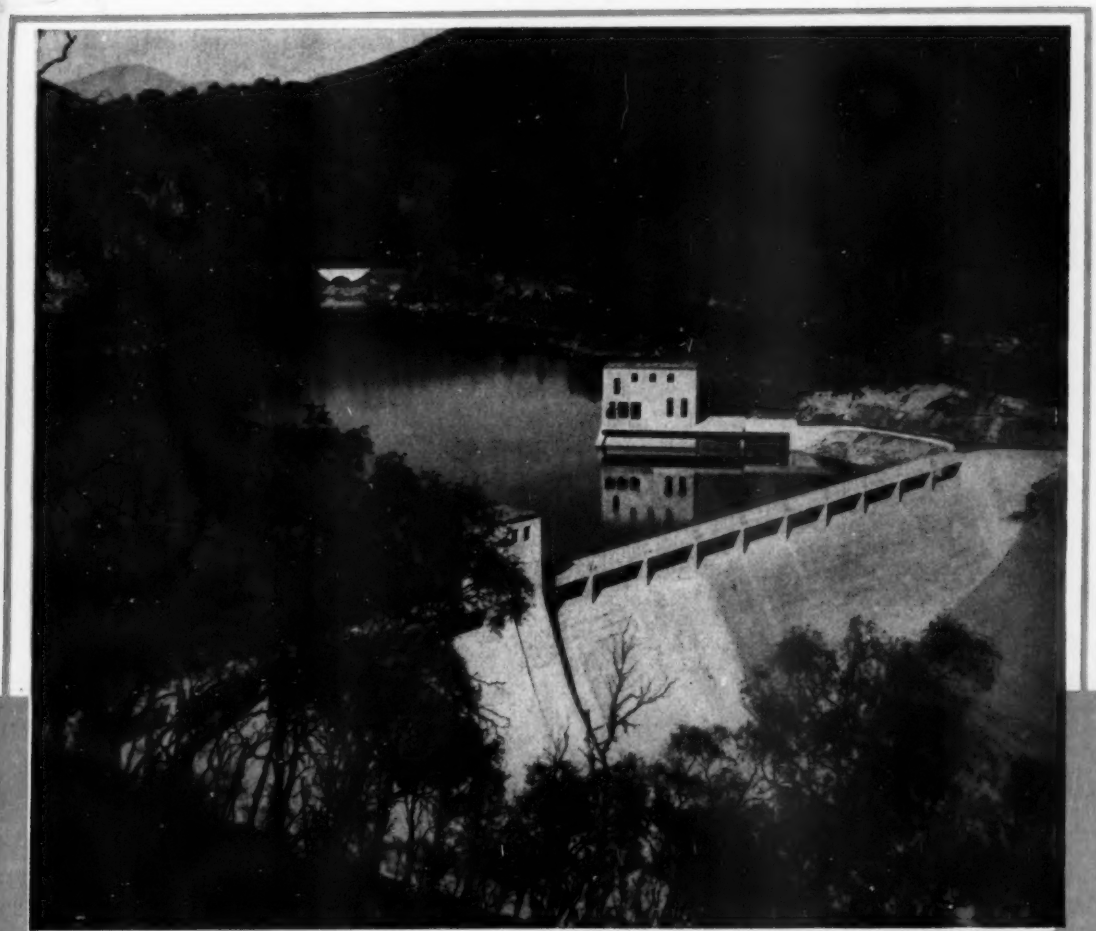
Water Power

INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

PRICE 2/6 MARCH 1960

CONTROL EQUIPMENT

TEXAS ENGINEERS LIBRARY
COLLEGE STATION, TEXAS

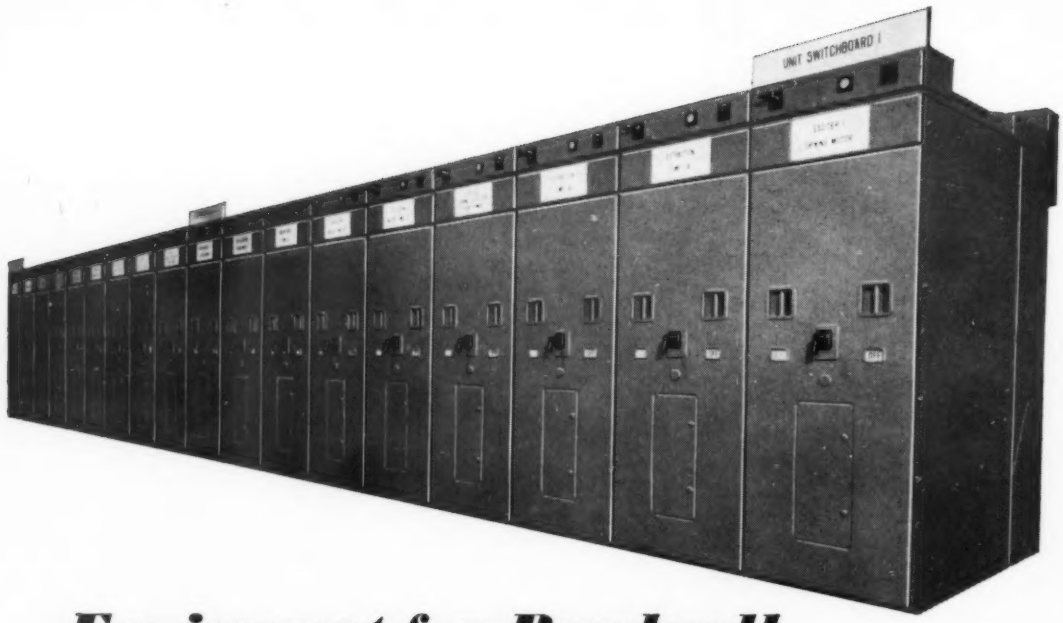


MAR 30 1960

There is a Glenfield product for almost every flow control or associated purpose at the Headworks, in the Pipelines or at the Power Station.

Glenfield
GLENFIELD & KENNEDY LIMITED KILMARNOCK

Head Office and Works
KILMARNOCK · SCOTLAND



Equipment for Bradwell

All the switchgear comprising the main 132-kV air-blast circuit-breakers, 6·6-kV, 3·3-kV, and 415-volt air-break equipment for auxiliary supplies, together with its associated control apparatus for Bradwell Nuclear Power Station is being supplied by Reyrolle who are responsible also for the reactor control-rod heads, the fission-products detection equipment, and the machining of the graphite blocks.

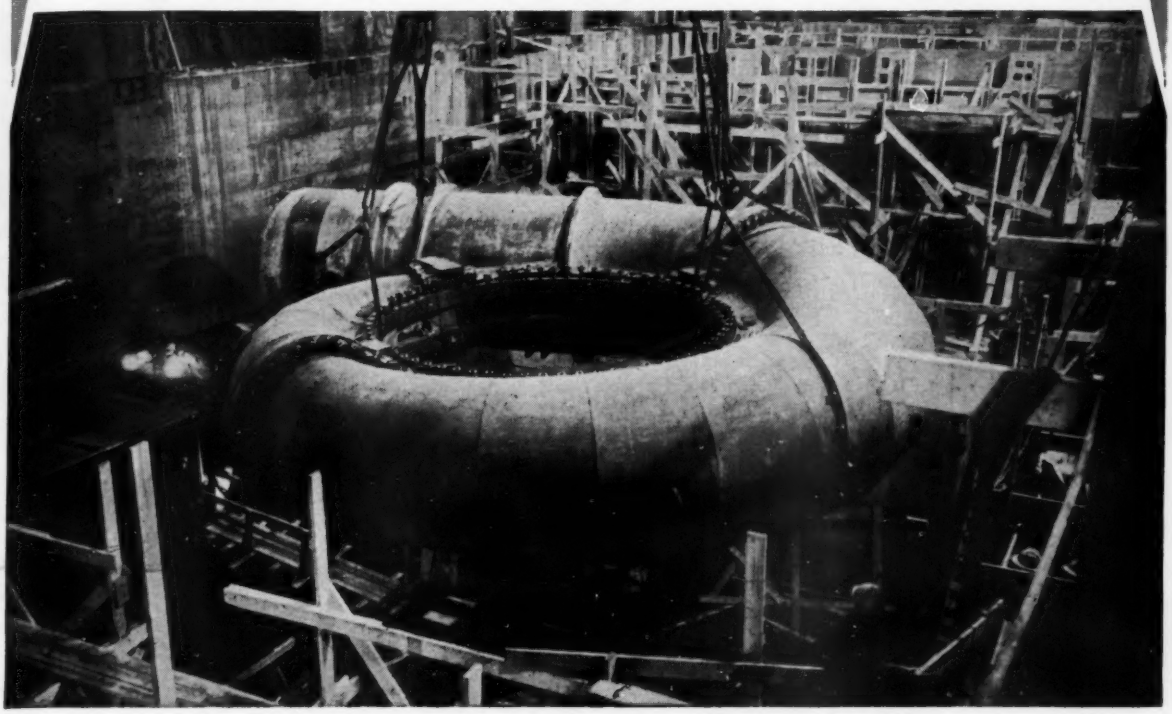
Reyrolle specialists in switchgear and control-apparatus

MEMBER OF THE NUCLEAR POWER PLANT CO LTD

A. Reyrolle & Company Limited · Hebburn · County Durham · England

AT BERSIMIS

World's largest high head turbines



RECORD OUTPUTS OF 200,000 h.p. DEVELOPED

At Hydro Quebec's Bersimis-Lac Casse Development in Canada, four 'ENGLISH ELECTRIC' water turbines have regularly supplied 520,000 kW to Quebec's power system from one of the world's most powerful hydro-electric stations. On occasions 200,000 h.p. has been developed from a single turbine under a net head of 840 feet. This establishes a world record for hydro-electric units, being more than 10% greater than the output of any other high head turbine. These turbines of 'ENGLISH ELECTRIC' design were supplied by English Electric Canada, a division of John Inglis Co. Ltd. and manufactured at Toronto.

'ENGLISH ELECTRIC'
water turbines

THE ENGLISH ELECTRIC COMPANY LIMITED, MARCONI HOUSE, STRAND, LONDON, W.C.2
ENGLISH ELECTRIC CANADA (A DIVISION OF JOHN INGLIS CO. LTD.) ST. CATHARINES, ONTARIO
Offices and representatives throughout the world

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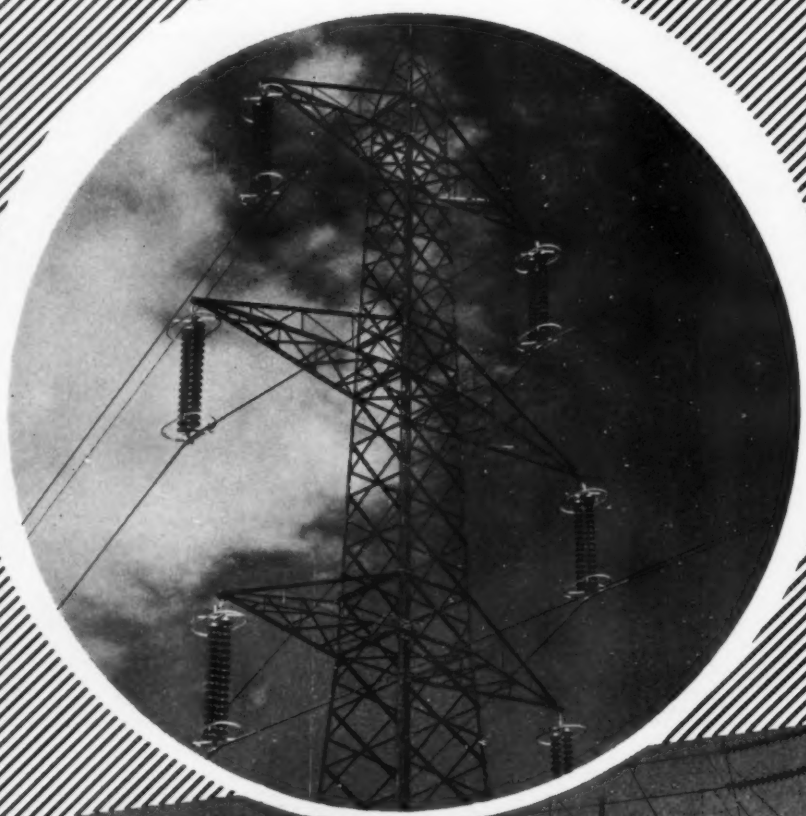
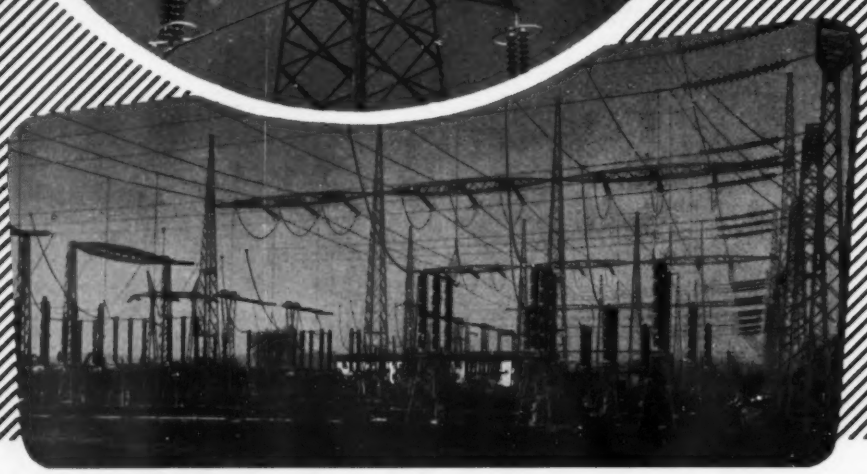
SALVI





For 30 years Messrs. A. Salvi and Company, Milano, Italy, have specialized in the design and manufacture of complete equipment for Overhead Transmission Lines, including Compression Dead End Assemblies and Joints. The Works of the Salvi Company are engaged exclusively in the production of high grade fittings for High Voltage Transmission Systems, up to and including voltages of 220/380 KV and for all sizes of Copper, A.C.S.R. and Aluminium Alloy Conductors.

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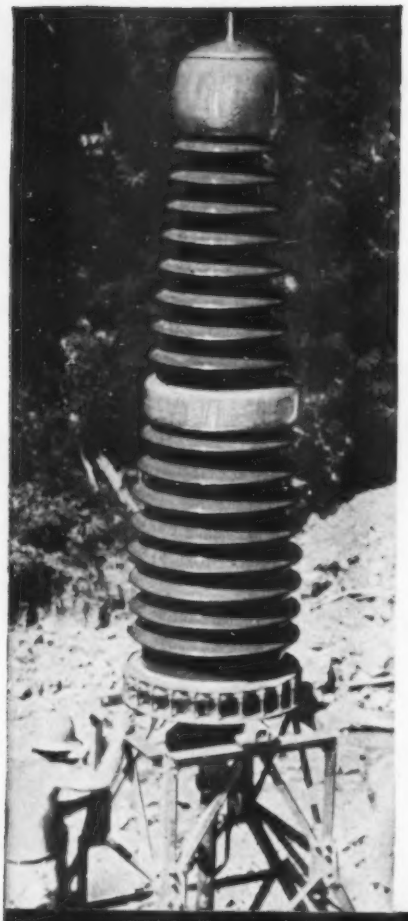
Escher Wyss Ltd. Zurich/Switzerland



In the Snowy Mountains region of Australia, a great river, the Snowy, and its tributary, the Eucumbene, are being diverted from an easterly course to irrigate the western plains of New South Wales and Victoria. On its journey westward this water will fall more than 2,000 ft.—a staggering power potential which, through a chain of hydro electric power stations, will eventually produce enough electricity to pay for the whole vast enterprise. For one of the first of these power stations, the T.1. on the River Tumut, a tributary of the Eucumbene, Pirelli-General have manufactured and installed the highest voltage oil-filled cables ever made in this country. Transmission of power at 330 kV. 3 phase 194 M.V.A. (340 amperes phase) along a tunnelled route from an underground generating station to an outdoor switchyard some 1,600 ft. distant *on the other side of the River Tumut*

AUSTRALIAN SNOWY MOUNTAINS HYDRO-ELECTRIC AUTHORITY

FIRST with 330 kV OIL-FILLED CABLES

proved a formidable undertaking, and the seven cables, all of which were installed in single lengths of 1,625 ft. without intermediate joints, were carried on the bridge shown in the photograph. Pirelli-General are proud to announce that their contract to provide a vital link in this great Commonwealth enterprise has now been completed.

pg

PIRELLI-GENERAL
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Question to Power Line Builders:

Is this your problem?

Simple? Maybe . . . but splicing electrical conductors — even if they are Feral Cable — has to be done properly if the finished line is to be a first-class job. In fact, the splicing is of A1 importance for the proper functioning of any transmission line. It is not only a matter of knowing how it should be done, but of seeing that the work is carried out correctly at every joint.

For good electrical connections, both the conductor wires and the aluminium sleeve have to be carefully cleaned before the splice is made. It is important, too, that the sleeve should extend for an equal distance on either side of the joint. Other precautions are also necessary, such as seeing that the steel core is not damaged when the outer layers of aluminium conductor are cut away.

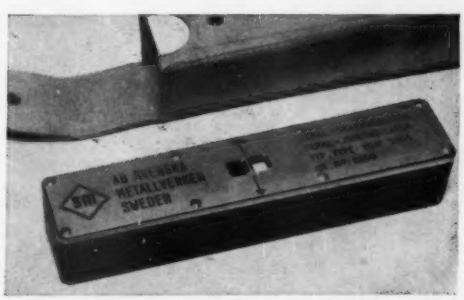
When customers are confronted with problems of line construction, Svenska Metallverken is always prepared to help in finding solutions by drawing on the extensive know-how which is available in Sweden. Come to think of it, there's a lot of know-how already gone in to making Feral Cable — *reliable* Swedish ACSR — available in such quantity and quality.

When planning power lines, consult

SVENSKA METALLVERKEN

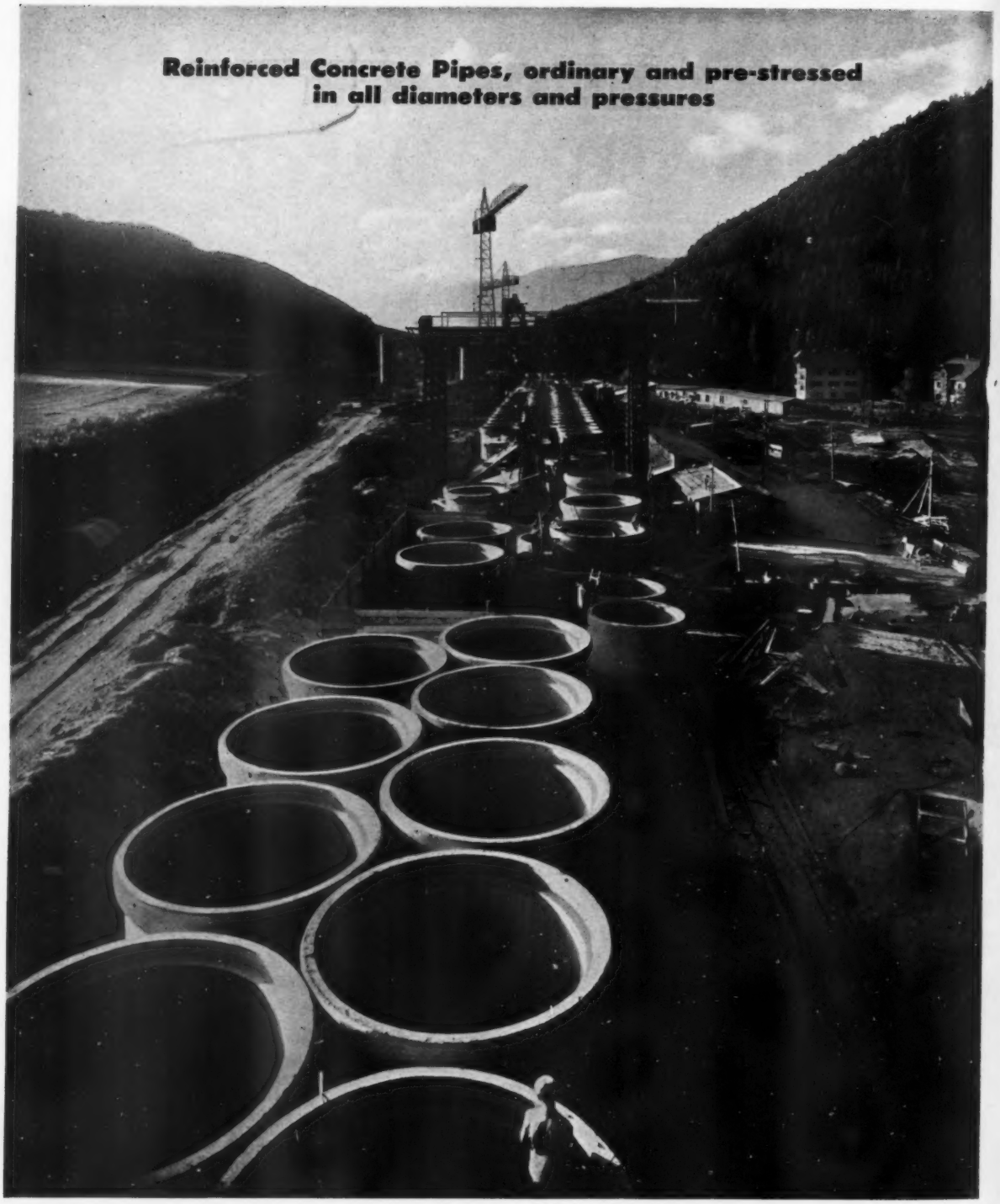
Manufacturers of Feral Cable

Job done properly? When once a sleeve has been clamped on, it may be difficult to see whether it has been properly positioned over the joint. To provide an easy method of checking, Svenska Metallverken has developed this Position Gauge, which shows, quickly and precisely, whether the sleeve is centred or not.



All tools and fittings necessary for ACSR line construction are supplied by Svenska Metallverken, in addition to the Feral Cable. When required, too, experts are sent out to help line builders with construction problems.

FERAL CABLE DIVISION SWEDEN VÄSTERÅS · SWEDEN



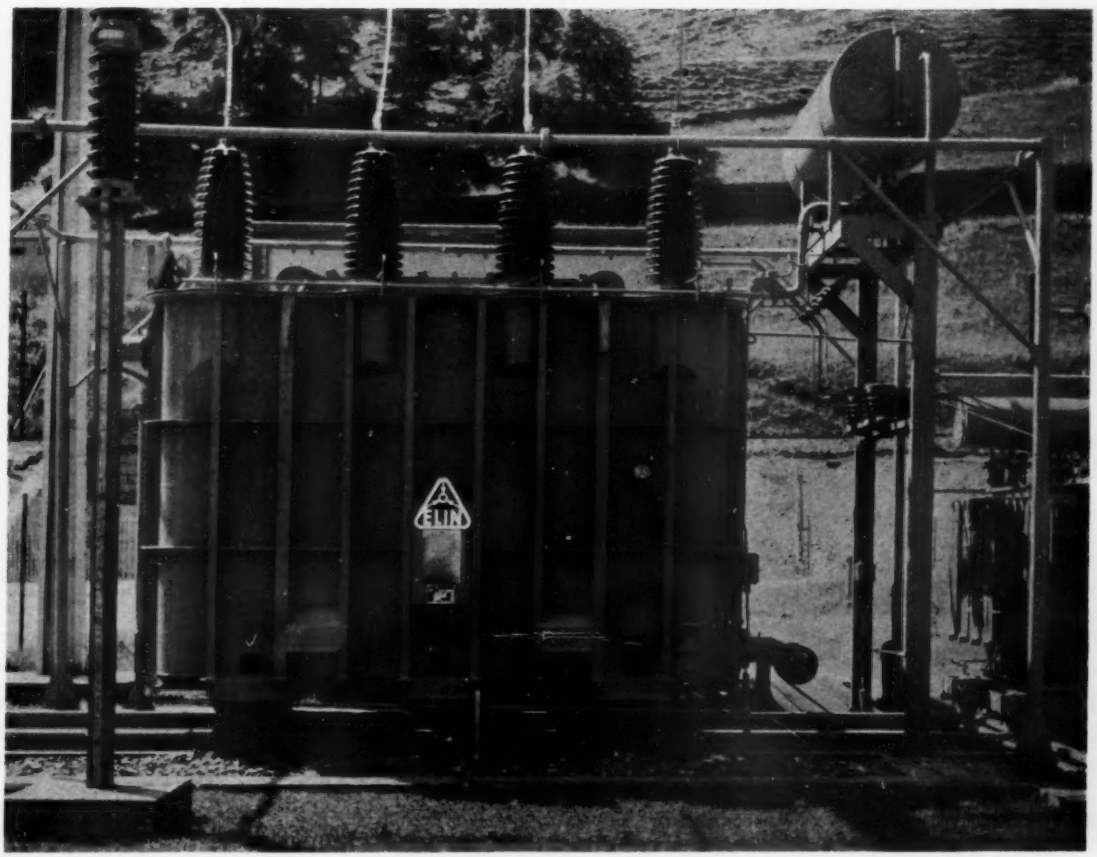
Pre-stressed reinforced concrete pipe, diameter 3.30m. pressure 9 atm. Brunico hydro-electric power station, Italy. Soc. Montecatini

SACAIM

Soc. p. Az. Cementi Armati Ing. Mantelli

VENICE (ITALY) - Accademia 979/A - Telephone 85.060

LARGE TRANSFORMERS



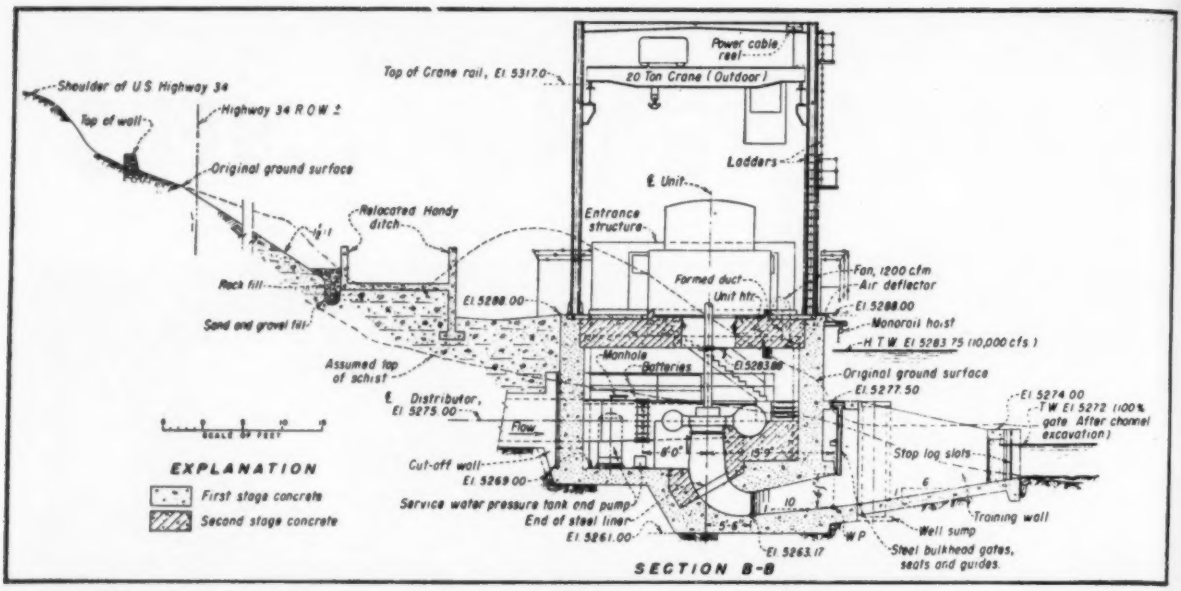
Three-phase three-winding transformer, 35/35/70 MVA, 10.25/10.25/116.5 kV, 50 cps, with external water cooling supplied to the Hydro Power Station Schwarzach of Tauernkraftwerke AG.

This transformer operates as unit transformer for 2 Nos. 35-MVA generators.

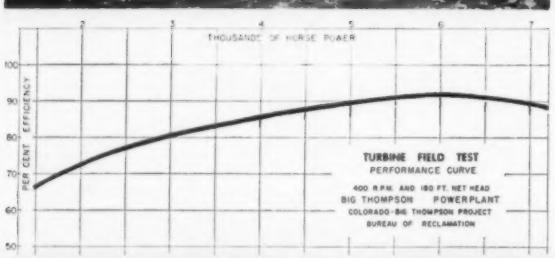
ELIN-UNION

Aktiengesellschaft für elektrische Industrie

Vienna—Austria



Leffel Turbine Installed in Bureau of Reclamation's Big Thompson Power Plant



A vertical shaft, reaction-type Leffel hydraulic turbine, rated at 6,300 HP at 400 RPM under a 180 foot net head, was selected by the United States Bureau of Reclamation to drive the generator in the Big Thompson Power Plant at the east entrance to the Big Thompson River Canyon eight miles west of Loveland, Colorado. This plant is the last of six power plants to be built as a part of the Bureau's Colorado-Big Thompson Project.

Successful installations in all parts of the world testify to Leffel's ability to design turbines for maximum efficiency and build them for maximum reliability. And every Leffel turbine is backed by nearly a century of experience in the more efficient development of power from water. This experience, through consultation with Leffel engineers, is available to you without obligation for help in the planning of your next project. Be sure to take advantage of it.

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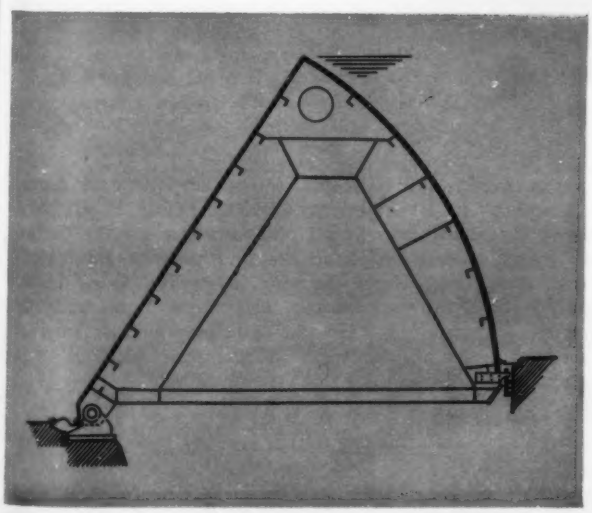

HYDRAULIC STRUCTURES

Sector weir of 50 m clear width and 4.55 m water head in the River Elbe at Geesthacht near Hamburg. Illustration shows the gate in course of erection. Sector weirs are hydraulically operated submersible gates moved by regulation of the water enclosed in the sector chamber. As opposed to drum gates, they are particularly appropriate for weir plants in rivers where comparatively slight variation in the water level occurs.

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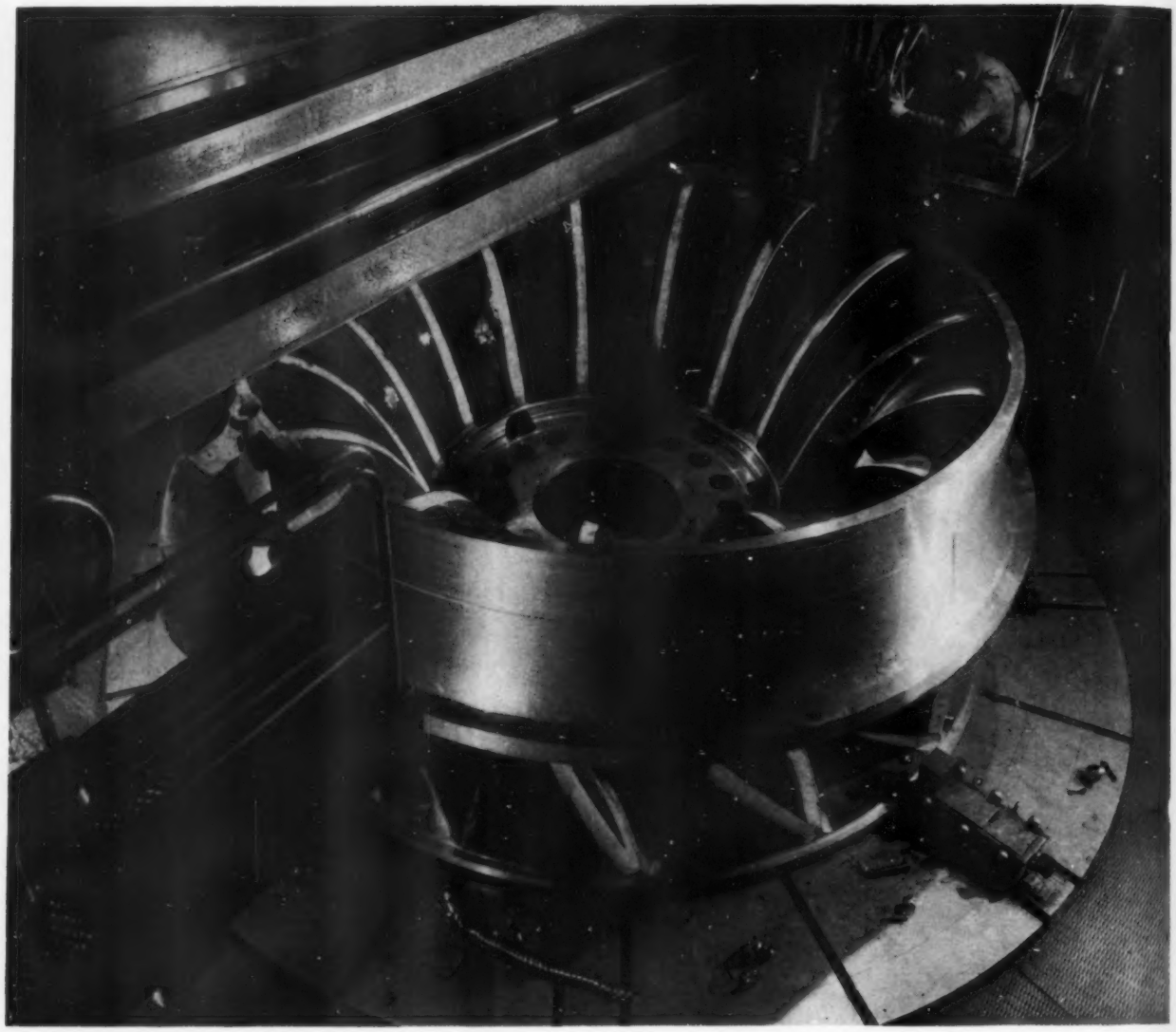

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Output 125 000 kW — Head 139 m
Speed 187.5 rpm.

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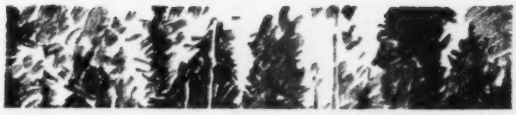
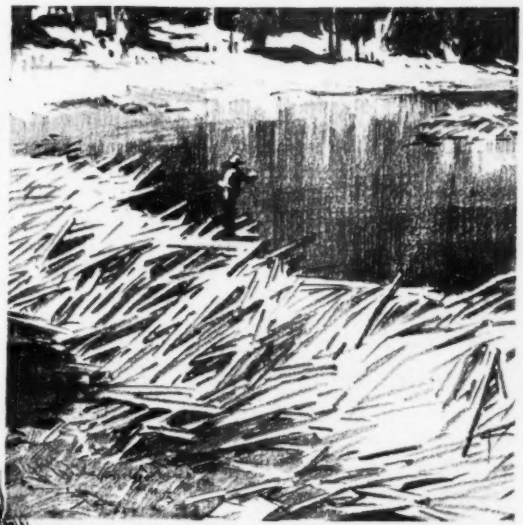


ACHIEVEMENT IN THE WILDERNESS



Cemented with frozen mud, the beaver's lodge shelters him from the elements and his many enemies. The lower chamber, entered from underwater, is his 'dining room,' while above it, the sleeping space is lined with cedarwood shavings or peeled twigs.

GIVE the beaver a valley, a stream and enough trees and there's no limit to the efforts he'll make. Dams a thousand feet long containing as many tons of material, holding back 'ponds' thousands of acres in extent—canals, stretching for hundreds of yards to a particular stand of timber—two-storey 'houses' sometimes forty feet in diameter—a strange and wonderful 'civilisation' flourishing where once the forest stood unchallenged.

On an infinitely greater scale but with the same inexhaustible energy and aptitude for the job we are creating the mechanism of modern life in places which for centuries have withstood the encroachment of man. Like the beaver, we are eager to build —and the wilderness is a challenge to be met and conquered.

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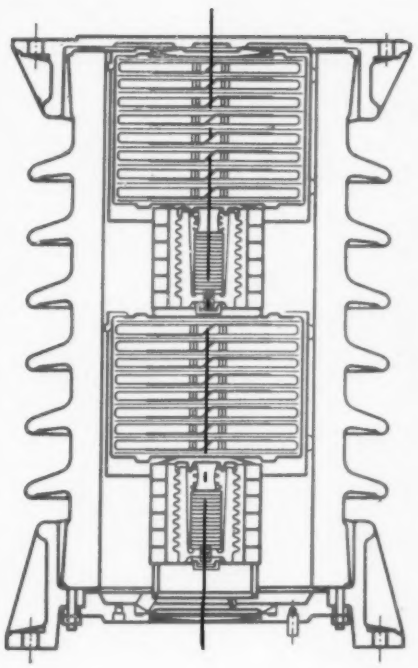
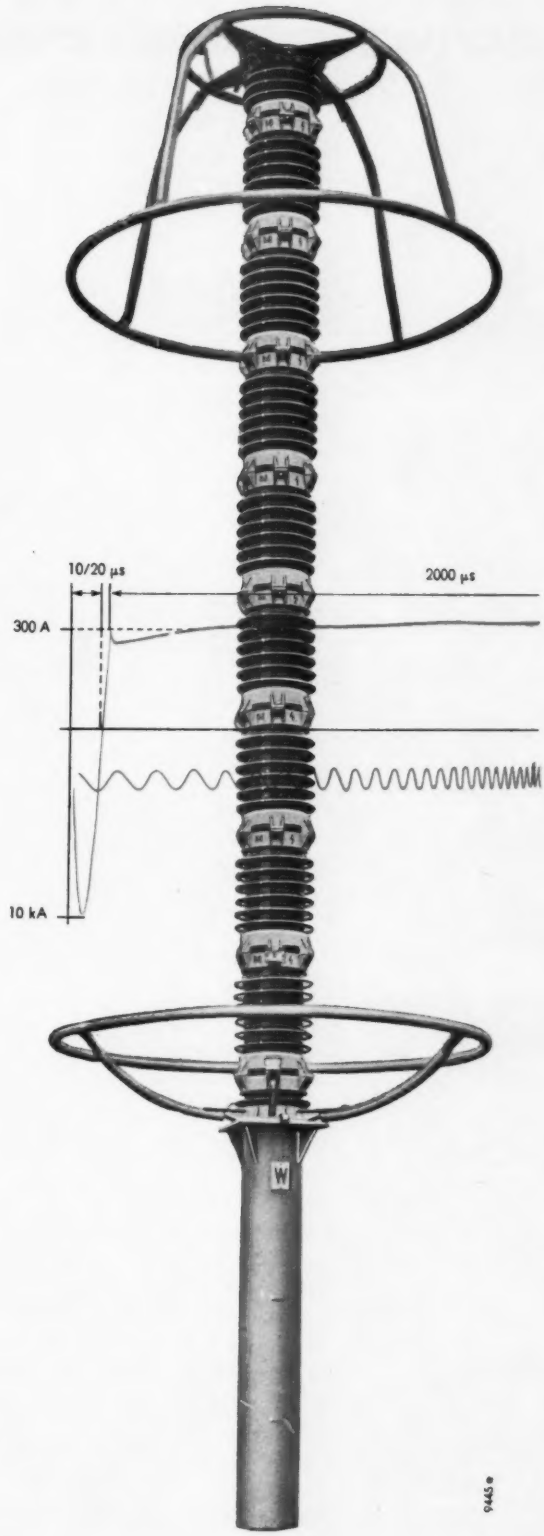
Revolutions - - - - - - - - - 375
Weight of Spiral Casing 110 tons
A. S. KVÆRNER BRUG, OSLO NORWAY

AEG





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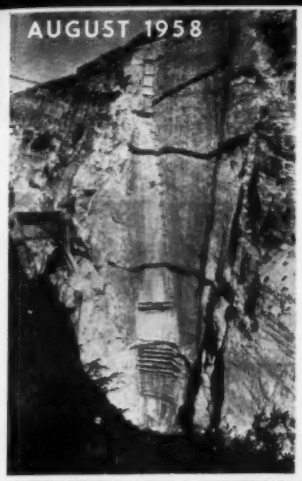

S.A.D.E.

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MAX. HEIGHT 873 ft.
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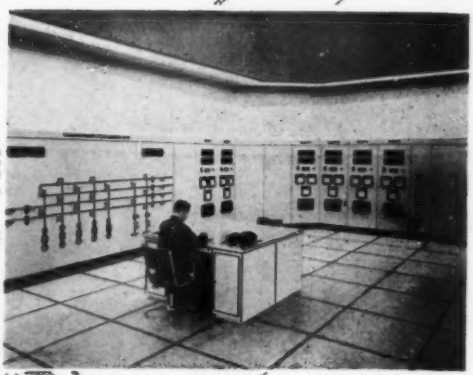
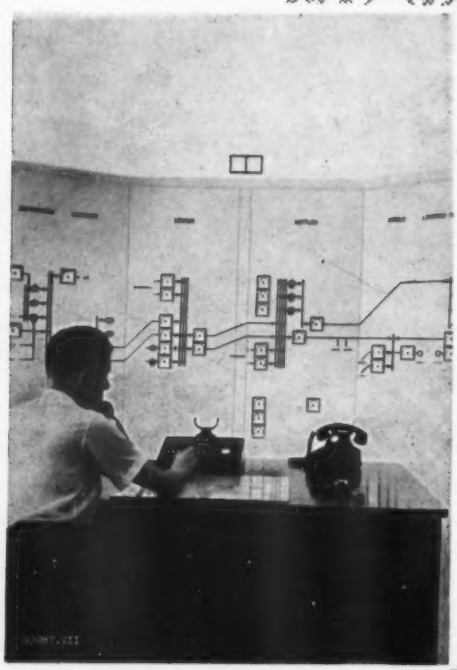


TELECOMMUNICATION



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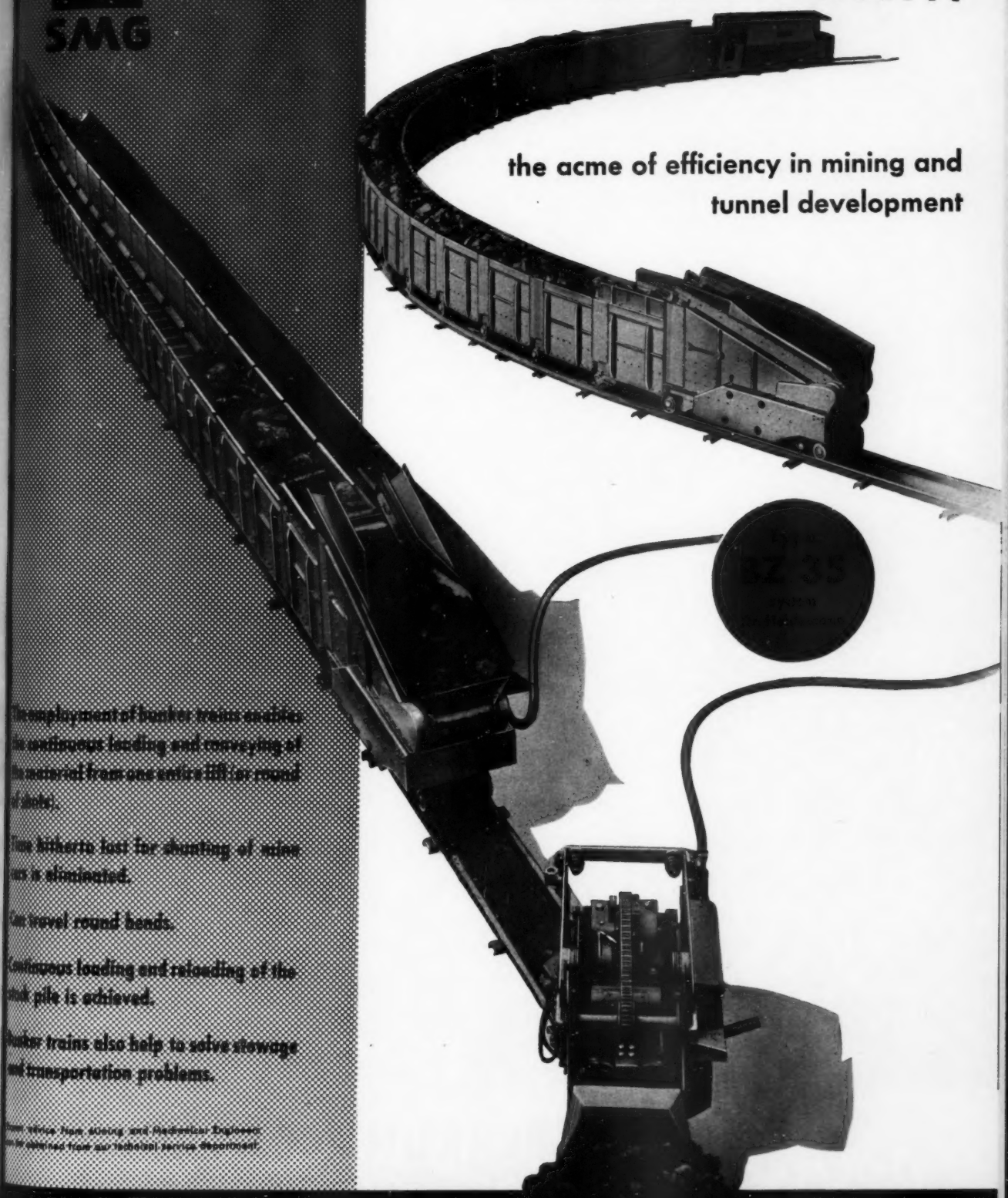

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261	Grønsdal	Norway	177	302	2200–1900	255	12–23	1	1947
262	Dale III	„	311	737	2000–1400	700	12–35	1	„
263	Grytten	„	424	374	900–800	1070	8–22	1	„
264	Maudal II	„	370	889	1650–1450	900	12–30	1	„
268	Skjerka II	„	340	1502	2100–1650	1240	22	1	„
272	Sand	„	320	181	500–450	1650	7–10	1	„
273	Søre Sunnmøre	„	377	235	1100–850	682	9–23	1	„
275	Glomfjord (Flow Lines)	„	—	368	550	3037	7	1	„
277	Pykara IV	India	936	3000	1067–991	3025	12–49	1	„
283	Lund	Norway	251	190	700–550	1112	8–10	1	1948
284	Vadheim II	„	313	222	1050–850	676	9–17	1	„
286	Festa	„	210	194	1300–1200	407	10–14	1	„
288	Kåven	„	117	180	1600–1500	360	10–12	1	„
290	Vinstra I	„	447	1020	2400–2200	387	14	1	1949
291	Tafjord	„	400	400	1750	608	8–14	1	„
292	Åbjøra	„	439	739	2300–900	666	12–35	1	„
293	Poringalkuthu	India	181	2000	2590–1320	887	11–30	3	„
294	Machkund	„	260	1450	1600–1450	500	11–32	3	„
298	Sueva I	Colombia	233	88	800–100	514	5–10	1	1951
299	Sueva II	„	187	135	1200–1000	509	6–12	1	„
302	Trevallyn	Tasmania	163	470	4420–1727	152	24	1	1952
304	Aura II-C	Norway	295	396	2200	416	12–44	1	„
305	Aura II-D	„	744	1112	1600	1212	12–44	1	„
306	Røssåga	„	247	1237	3400–3000	398	13–26	2	1953
309	Nore	„	368	337	1800–1300	475	12–34	1	1954
313	Mocorongo	Colombia	331	657	2000–1736	1015	9–21	1	„
316	Hardeland	Norway	322	272	1300–1000	879	8–15	1	1955
319	Poringalkutha	India	181	480	2590–1320	887	11–30	1	„
320	Hjartdøla	Norway	587	1061	2600–1500	1145	10–49	1	1956
321	Machkund 2nd Stage	India	260	1500	1600–1450	500	11–32	3	„
322	Bhakra (Bulk Heads)	„	—	60	4450	—	17,5	–	„
323	Kaldåga	Norway	566	789	1300–1000	1803	8–23	1	„
329	Sande	„	90	225	600	3000	5	1	„
332	Gjuva	„	390	206	1200–800	875	8–14	1	„
334	Innset	„	187	400	3200–2000	253	14–22	1	1957
337	Neriamangalam	India	224	900	3353–1600	1359	12–17	1	1958
338	Kiewa I	Australia	—	5	1912–864	—	20	–	„
339	Fortun II	Norway	873	112	1600–1300	75	30–61	1	„
340	Vrenga	„	379	440	1300–900	1568	8–11	1	„
341	Tyin II	„	1009	1485	1600–1200	1857	10–47	1	„

FERRUM MONTAGE A/S

OSLO · NORWAY

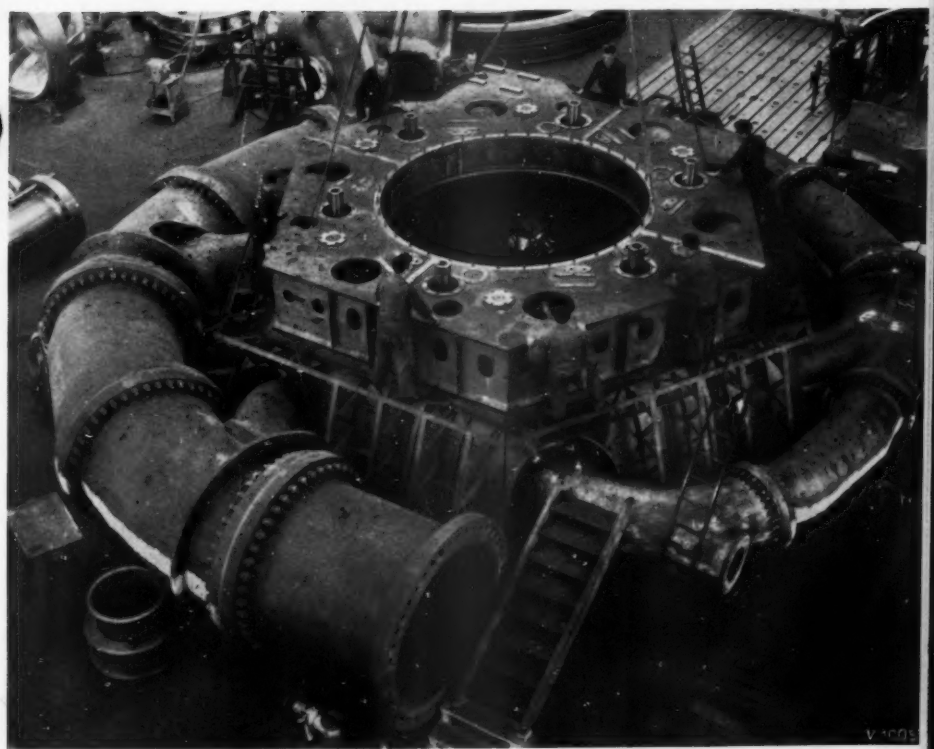
While the second of the two giant

136,000 HP, 1,770 FT HEAD, 6-JET

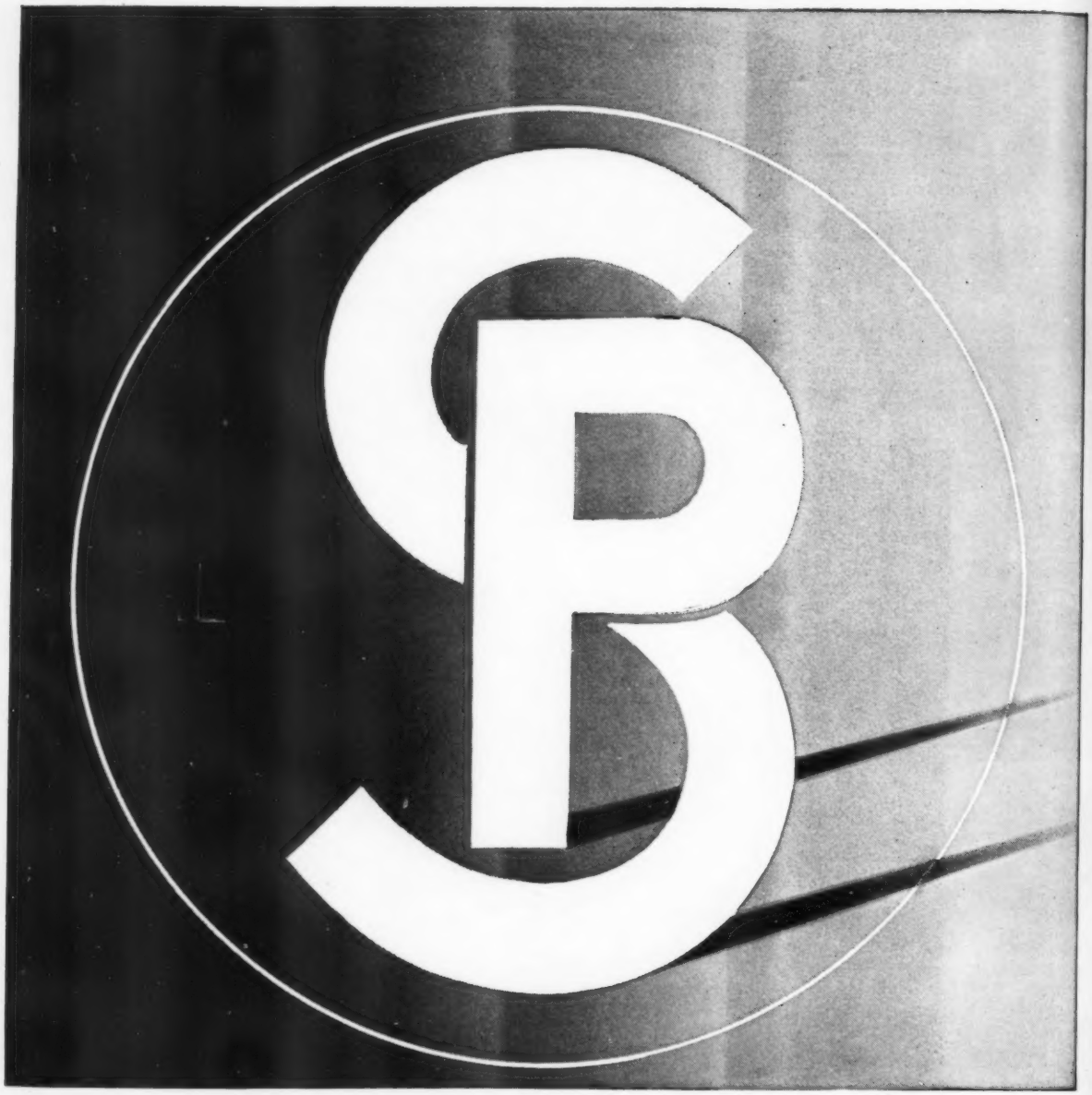
vertical-shaft VOITH Impulse Turbines for KUROBEGAWA POWER STATION (Japan) has just been shipped, the first set is being installed on site.

Second Kurobegawa Impulse Turbine:
Workshop erection of inlet casing with the 6 nozzle bends. One of the power nozzles is visible inside the pit liner on which the head cover is being placed before the runner can be lowered into position.

Runner and casing forms have been determined by extensive model tests in our "Brunnenmühle" Hydraulic Research Laboratory.



J. M. VOITH GMBH · HEIDENHEIM (BRENZ) · GERMANY



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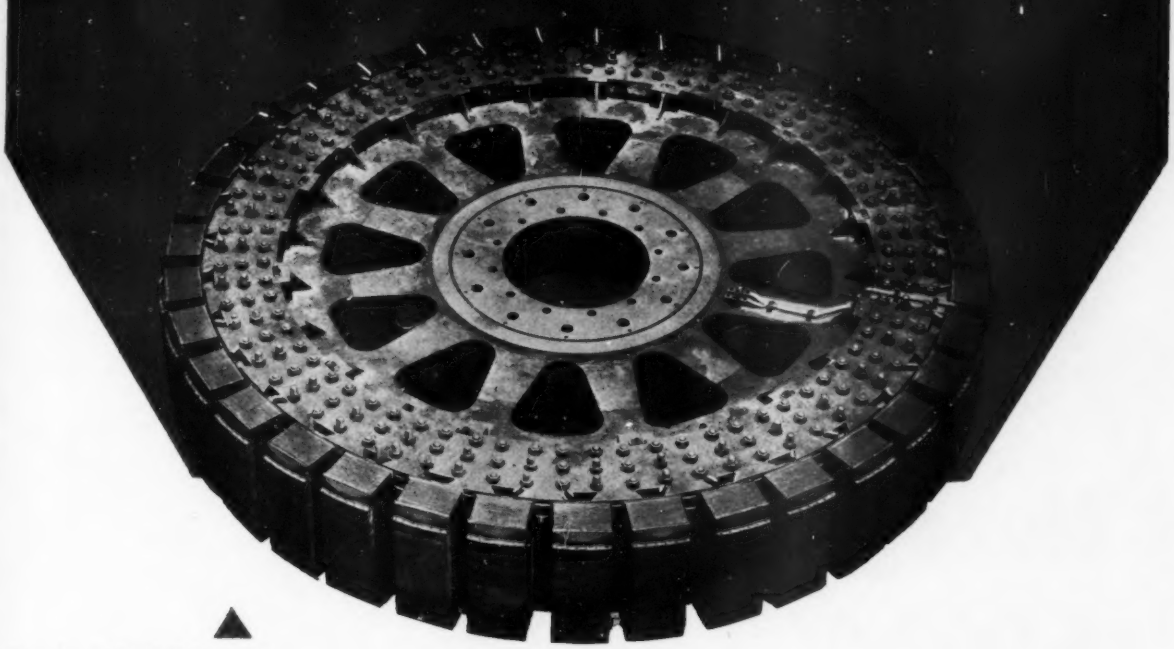
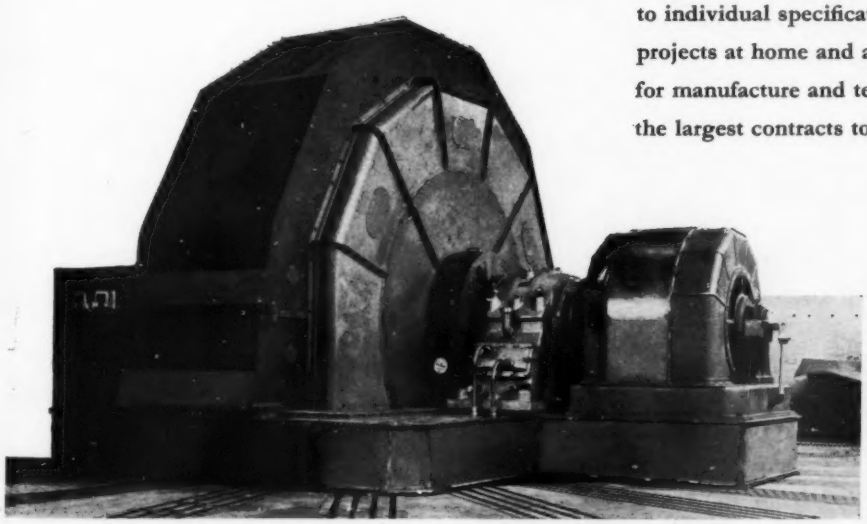
Hydro-Electric Generators



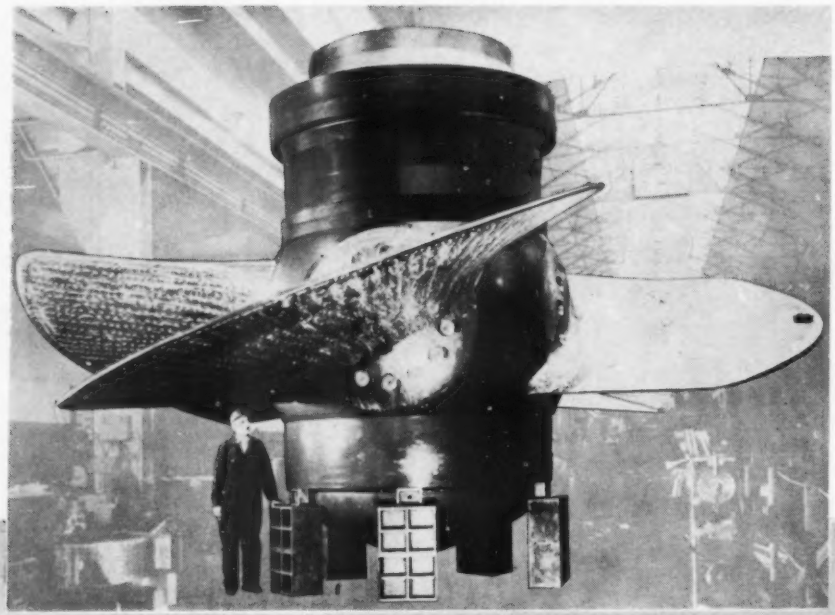
Rotor for a 3,500 kW 3.3 kV 167 r.p.m. vertical generator for the Lairg power station of the North of Scotland Hydro-Electric Board.

Bruce Peebles build generators, large or small, horizontal or vertical, designed to individual specifications, for hydro-electric projects at home and abroad. Ample resources for manufacture and testing enable the largest contracts to be undertaken.

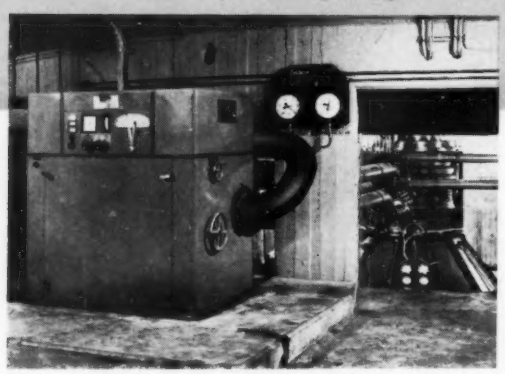


One of two 12 MW 11 kV 375 r.p.m. horizontal generators for the Shin power station of the North of Scotland Hydro-Electric Board erected for test.

BRUCE PEEBLES & Co Limited ENGINEERS EDINBURGH



Each of the Järkvissle turbines has a nominal rating of 59,500 HP at a head of 13·6 m (45 ft.) and a speed of 75 r.p.m. The runner diameter is 7·5 m (25 ft.)



Actuator and relay valve cabinet for electro - hydraulic governing

More than 5,000,000 HP

is being developed by KMW Kaplan turbines. If the turbines built by our licensees are included, this output can be increased to more than 7,000,000 HP, a figure which clearly shows that KMW is one of the leading manufacturers of this type of turbine. Our 40 years' experience covers all sizes of Kaplan turbines, including runner diameters of more than 8 m (26 ft.) and heads of more than 50 m (164 ft.). In December 1959 a new link was forged in the long chain of deliveries when the second unit at Järkvissle power plant, belonging to the Swedish State Power Board, was commissioned.

The arrangement of the machinery and the design of the control equipment at Järkvissle incorporate new principles applied for the first time in Sweden. The two units have a two-bearing rotating system with an umbrella type generator and with the thrust bearing on the turbine cover.

The thrust bearings, which are manufactured by KMW, are designed for a maximum load of 1,250 tons and have self-circulating oil system.

The station is equipped with electrical governors, and the design of the hydraulic part of the control equipment permits the actuator, the control valves for runner and gate servomotors, and the combinator gear to be grouped in a common cabinet. Hydraulic oil for runner pitch adjustment reaches the turbine through an oil pressure box on the turbine shaft below the generator. The return movement of the runner servomotor is transmitted to the control valve cabinet by electro-hydraulic means, thus the electrical return gear is the only piece of turbine control equipment on the upper part of the generator.

Järkvissle power plant will be remotely controlled from a neighbouring station.

AB KARLSTADS MEKANISKA WERKSTAD

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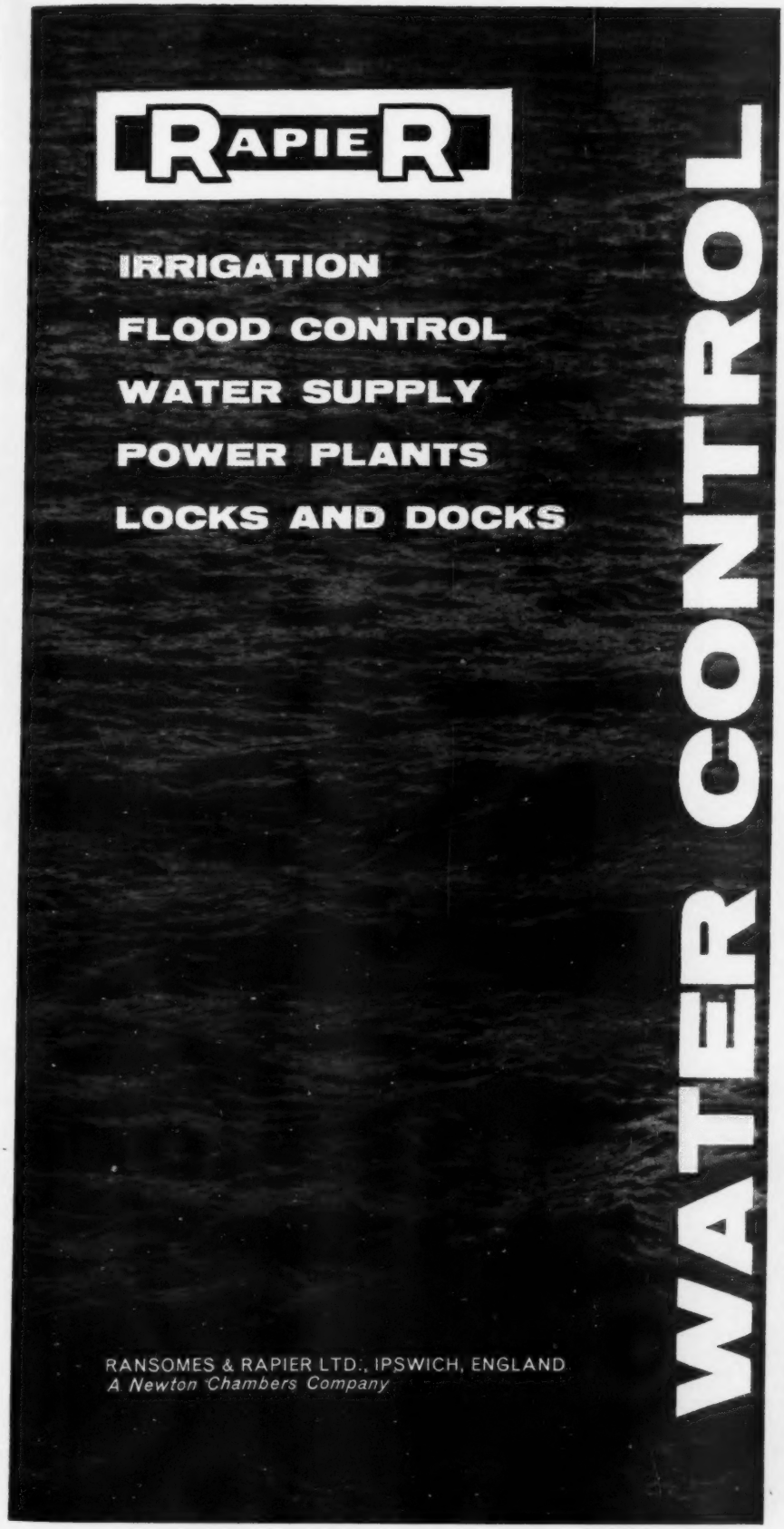
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HOBHOLE–ENGLAND
GLASGOW WEIR–SCOTLAND
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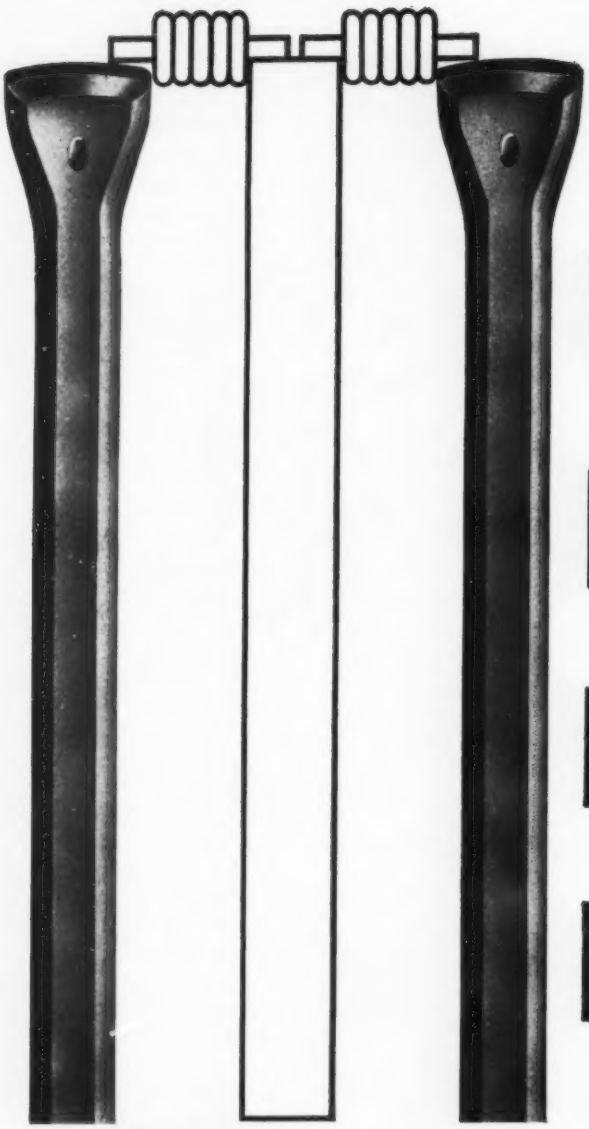

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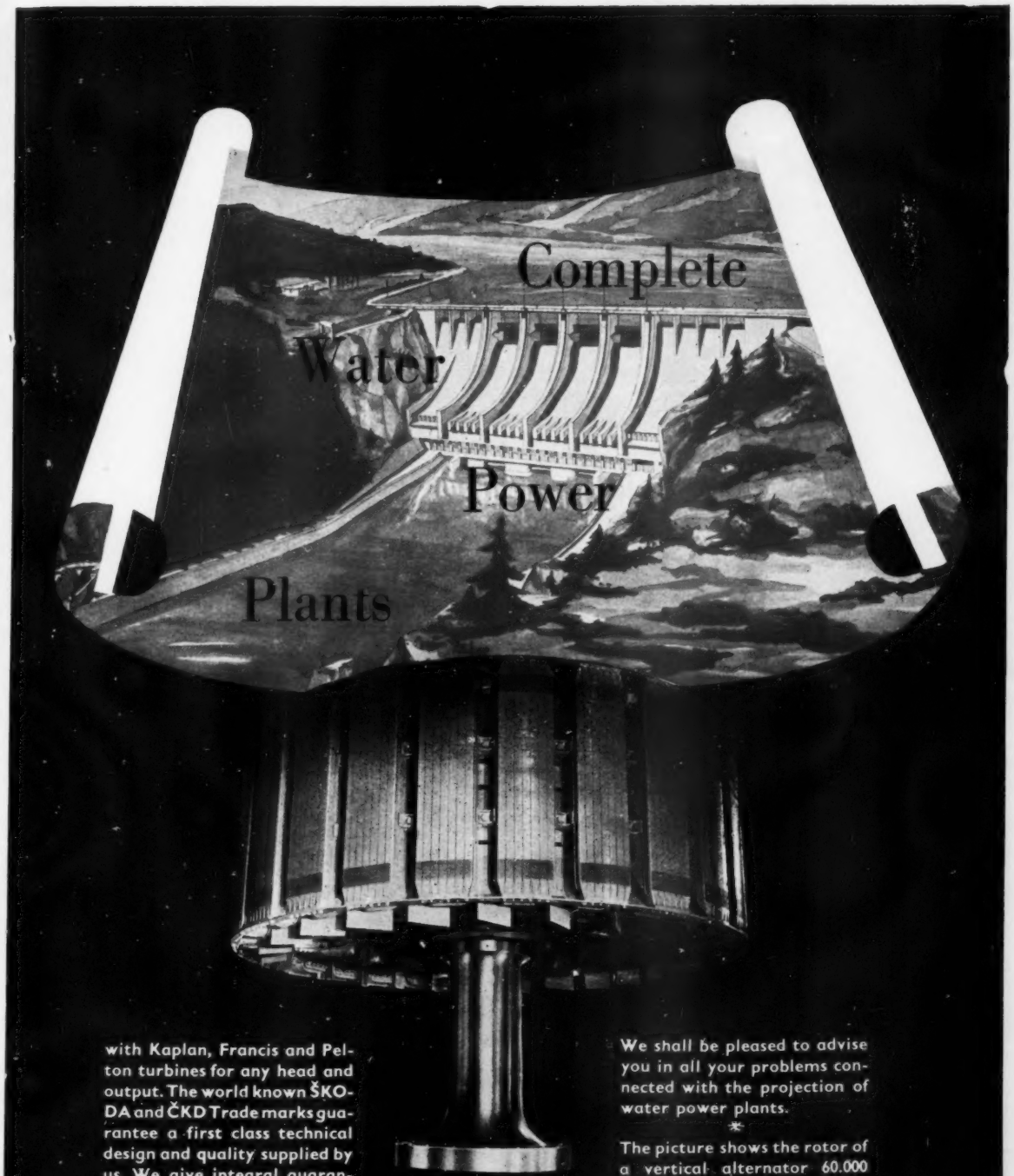

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The picture shows the rotor of a vertical alternator 60.000 kVA, 10,5 kV, 230.8 r. p. m.

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Henderson Cableways fit the description. Not only is each component built to the highest degree of engineering skill - Henderson Cableways are undoubtedly the most economical method of moving big loads on the majority of dam, barrage, bridge or viaduct contracts. Confirmation of this fact lies in the considerable number of cableways we have installed at vast projects throughout the world.

Henderson *CABLEWAYS*

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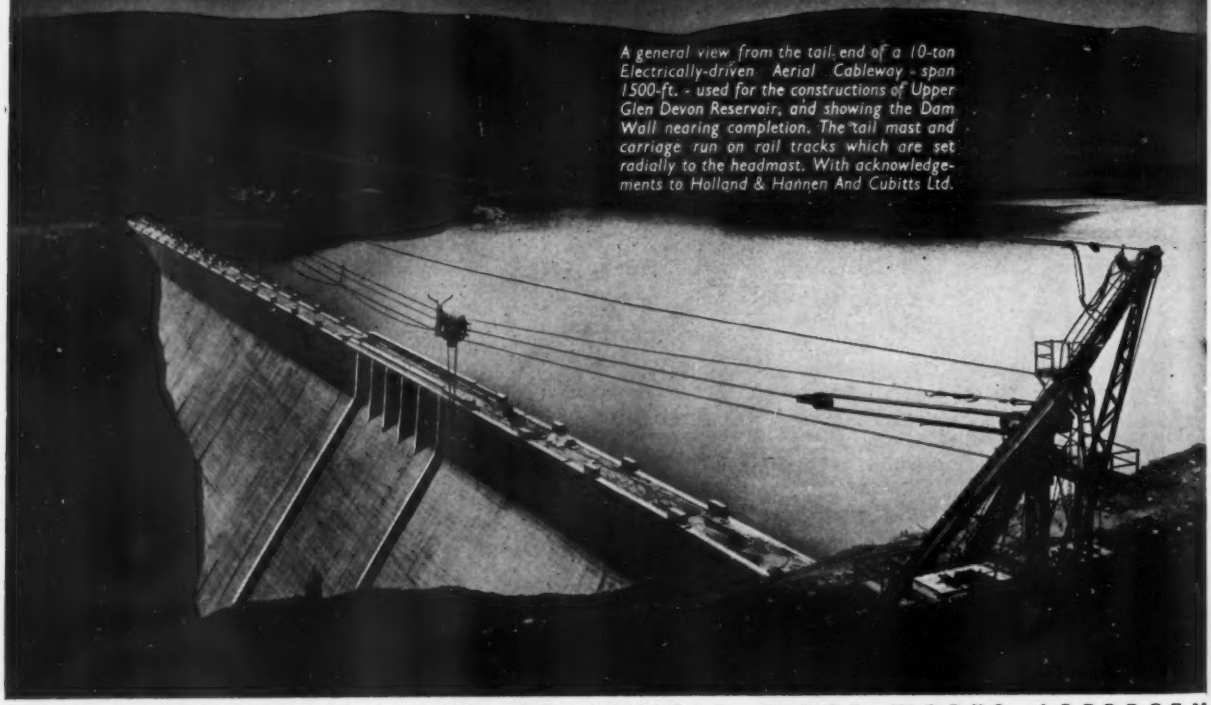
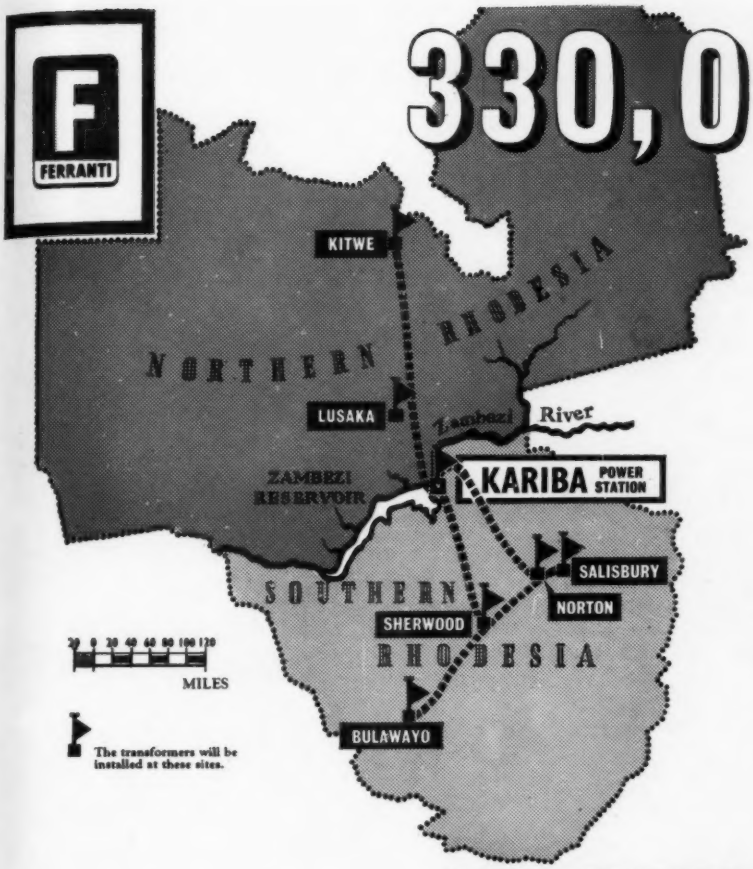


A general view from the tail end of a 10-ton Electrically-driven Aerial Cableway - span 1500-ft. - used for the constructions of Upper Glen Devon Reservoir, and showing the Dam Wall nearing completion. The tail mast and carriage run on rail tracks which are set radially to the headmast. With acknowledgements to Holland & Hannen And Cubitts Ltd.

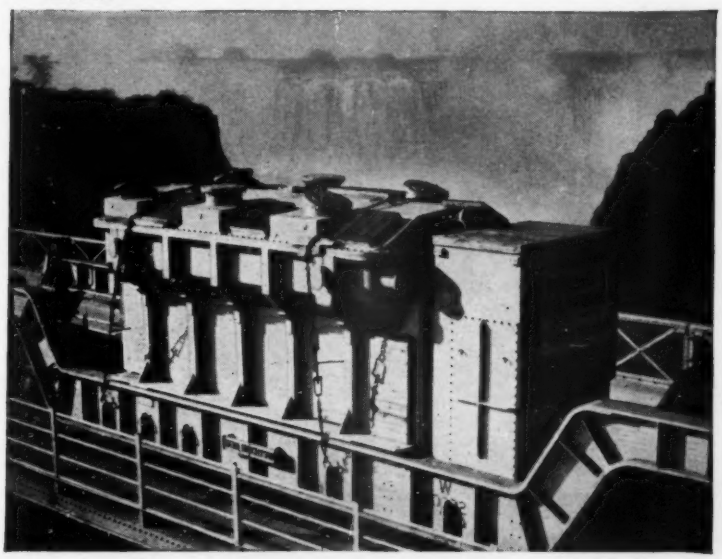
JOHN M HENDERSON AND CO LIMITED KINGS WORKS ABERDEEN

330,000 volts transformers for Kariba



The contract awarded to Ferranti Ltd. by the Federal Power Board, Rhodesia and Nyasaland, comprises two 120,000 kVA, 330/234 kV 3-phase auto transformers with series boosters, eight 60,000 kVA, 330/88 kV — one in commission at Norton — and four 60,000 kVA, 330/33 kV — one in commission at Salisbury — 3-phase double wound transformers.

The consulting electrical and mechanical engineers are Messrs. Merz & McLellan.



A Ferranti large power transformer crossing Victoria Falls bridge on its way to the Kitwe sub-station for the Kariba Hydro-Electric scheme. Two of these transformers on special well-wagons form part of the load on a goods train.

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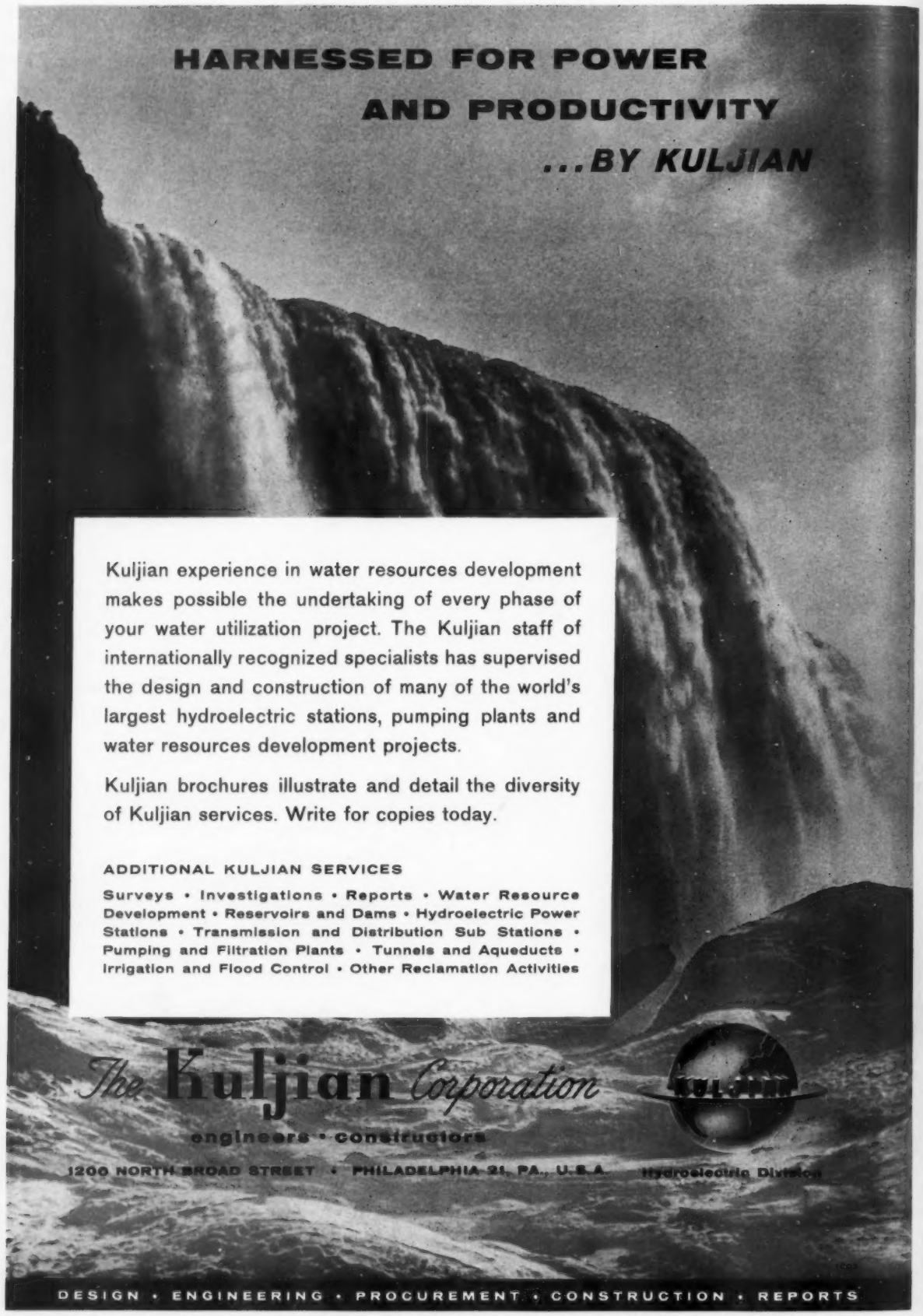
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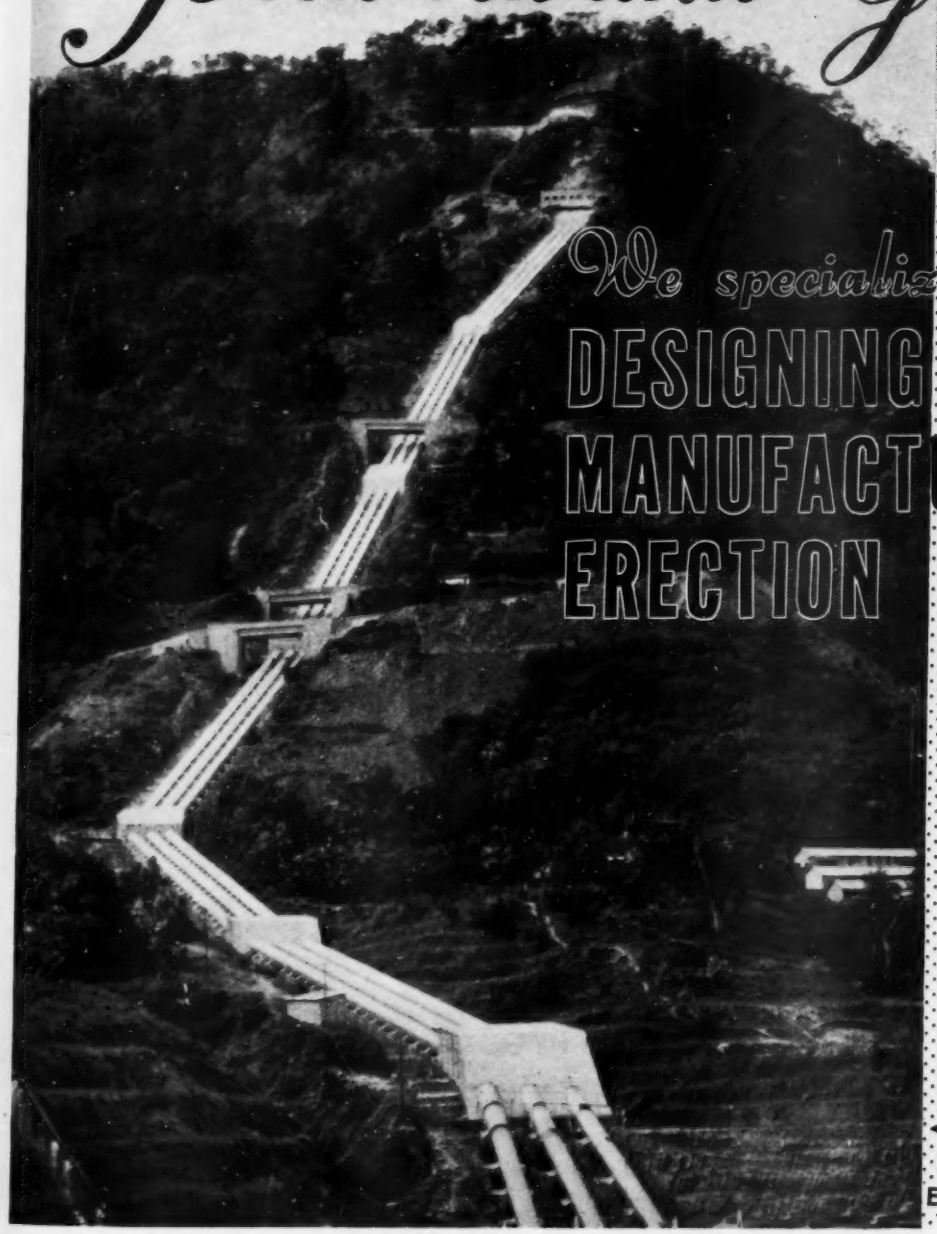

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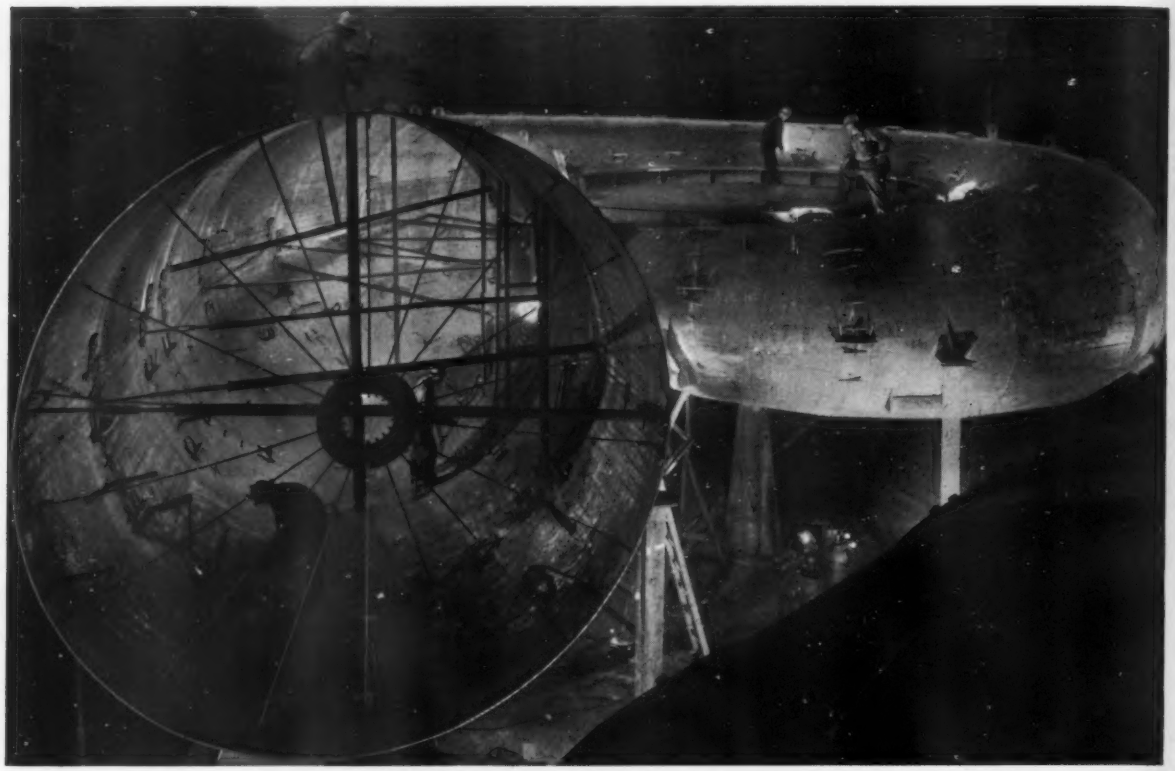
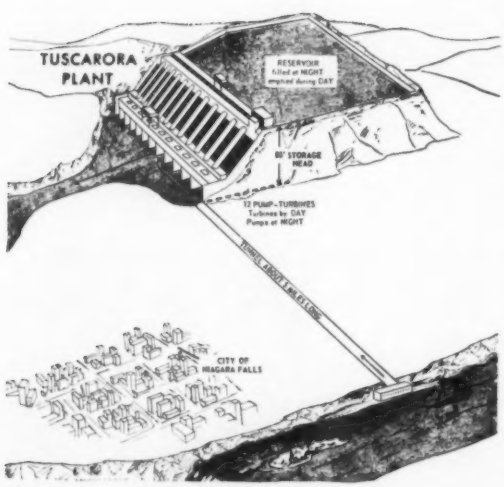


THE BIGGEST MADE IN THE U.S.A., this reversible pump-turbine scroll case has inlet diameter of 18 ft, measures 56 ft across. It's designed for one of Tuscarora's 12 Allis-Chalmers pump-turbines.

Now building 12 reversible pump-turbines for Tuscarora—

world's largest pumped-storage project

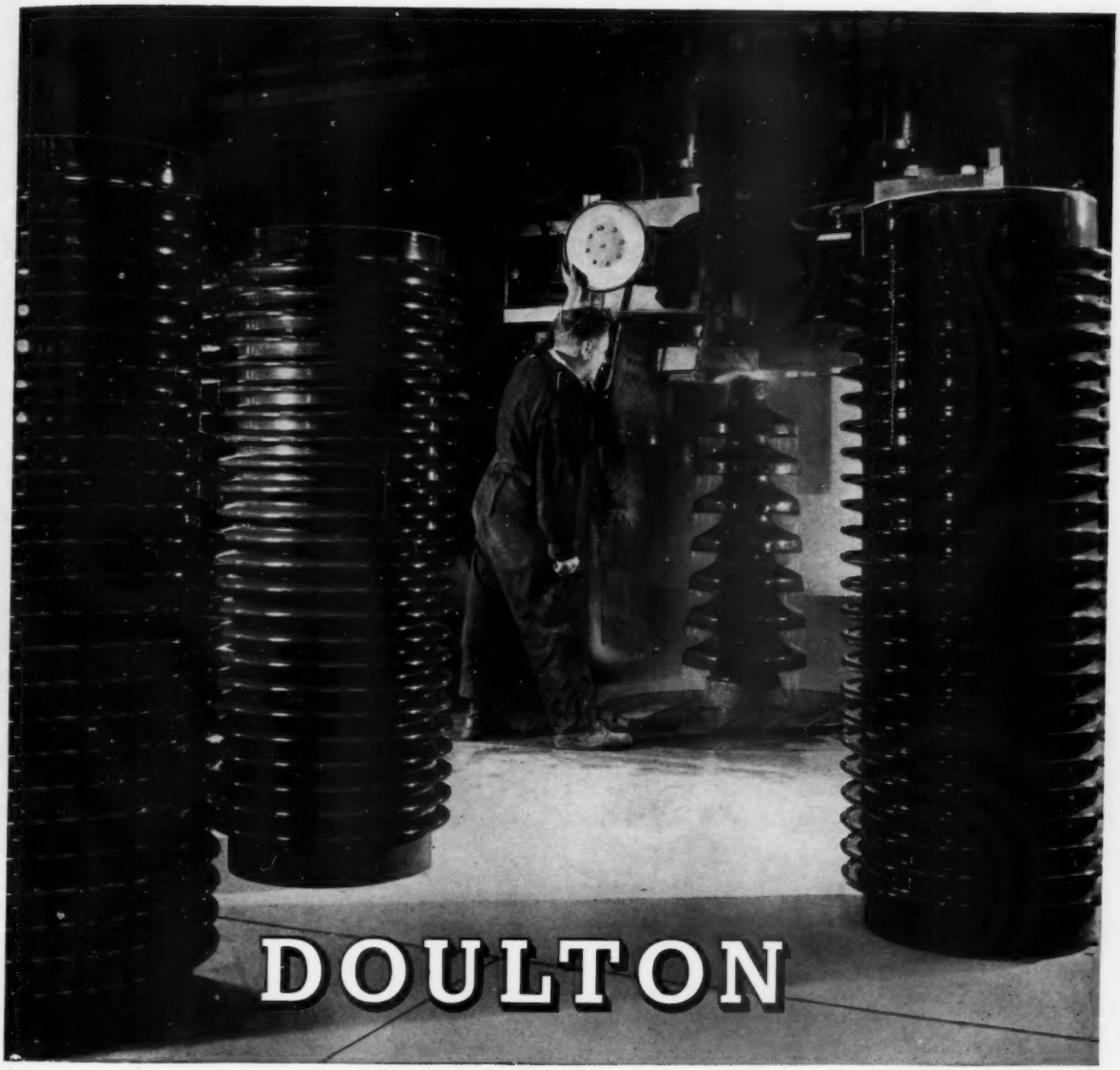


Power plant by day, pumping station at night — the New York State Power Authority's Tuscarora plant will capitalize on the hydroelectric power potential of the Niagara River without adversely affecting the scenic beauty of the Falls.

The largest project of its kind, Tuscarora will have 12 reversible pump-turbines . . . all designed and fabricated by Allis-Chalmers. As a turbine, each of these units is rated at 28,000 hp under 75-ft head. In reverse, as a pump, each is rated at 3400 cfs against 85-ft head. All will be direct-connected to Allis-Chalmers generator-motors — rating 25,000 kva at .8 P.F. as generators . . . 37,500 hp at 100% P.F. in reverse as motors.

The selection of Allis-Chalmers to design and build the above components came naturally. A-C is the only builder of complete reversible pump-turbine installations — with a record that includes the world's largest pumped-storage projects.

Look to Allis-Chalmers for leadership in the design, engineering and manufacture of hydraulic turbines and necessary accessories such as valves, pumps, trash rakes, water control gates and hoists. *For information, contact your nearby A-C office . . . or write* **Allis-Chalmers,** *Hydraulic Division, York, Pa.*



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A 132 kV Porcelain anti-fog cable ceiling end being ground to dimensional tolerances, as supplied to Pirelli General Cable Works Ltd. for use on C.E.G.B. contracts.

The three large 180 kV Porcelain bushings in the foreground are part of a consignment for the Canadian General Electric Co. Grinding and routine testing are the final stages before shipment to Toronto.

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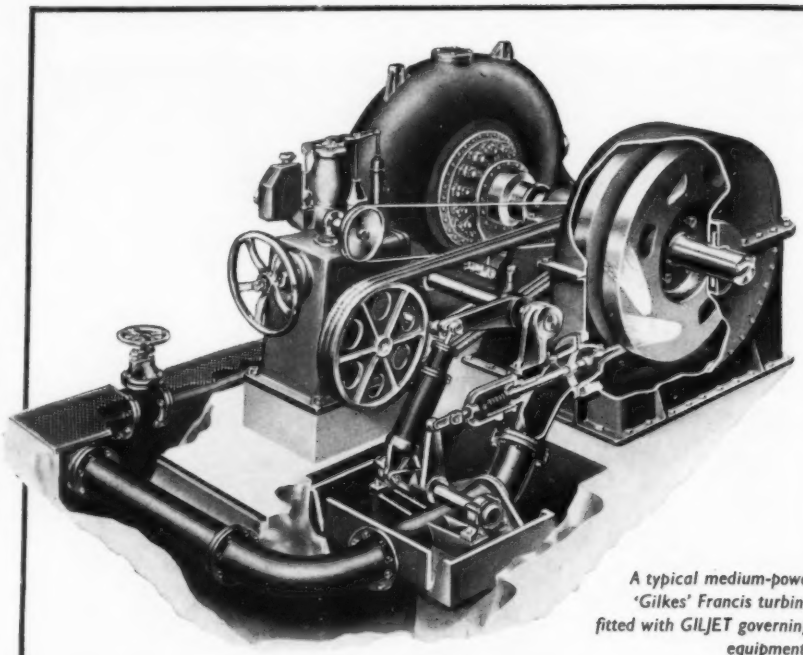
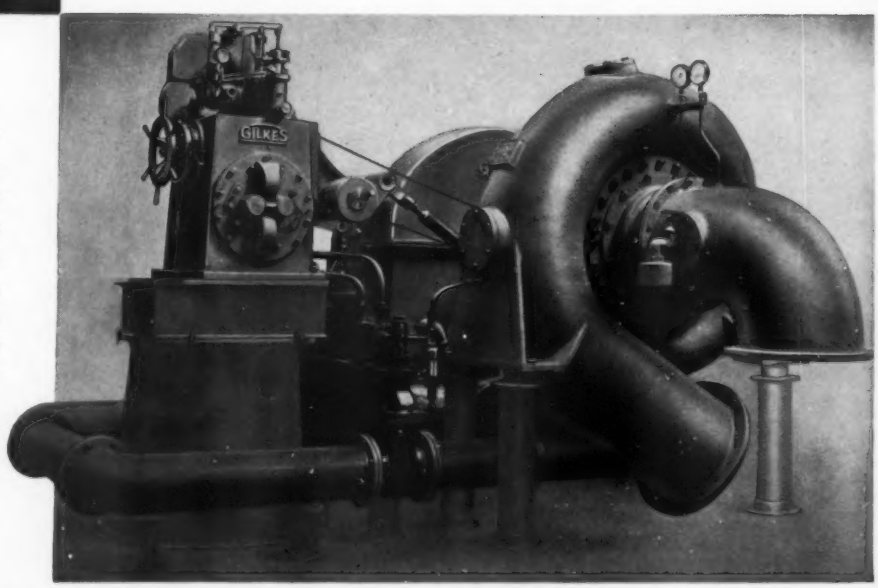
The GILJET Governing system provides a simple and effective method of governing Francis turbines operating on long pipelines. Its basic principle is the temporary application of a hydraulic load to compensate for the rejection of electrical load.
This action not only reduces pipeline pressure surges to a minimum but also restricts the speed rise to a low figure. For this reason the GILJET has superseded the conventional relief valve in many hydro-electric schemes.



A typical medium-power 'Gilkes' Francis turbine fitted with GILJET governing equipment.

THE GILJET GOVERNING SYSTEM

A 3,100 horsepower 'Gilkes' Francis turbine operating on 340 feet head and fitted with GILJET governing. This unit is installed in the North of Scotland Hydro-Electric Board's Kilmelfort Power Station. The pipeline is 4,700 feet long and there is no surge chamber.



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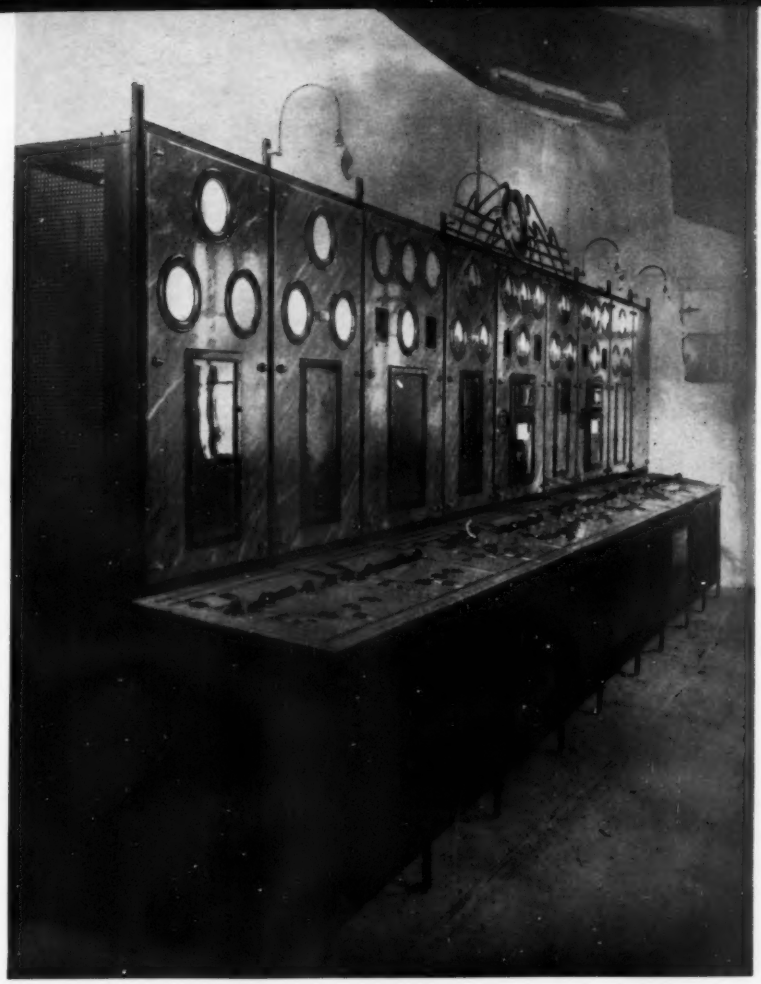

1919

SCARPA & MAGNANO established in April of 1919 as a small factory for the repair of electrical apparatus, expanded in the course of time its activity to include the construction of transformers and circuit breakers, thus always assuming major importance.

As main Contractor SCARPA & MAGNANO has projected and supplied in Italy and abroad important electric plants for production and transformation.

The exportation of the products of SCARPA & MAGNANO increased after the war and has steadily risen year by year gaining interest throughout the world.

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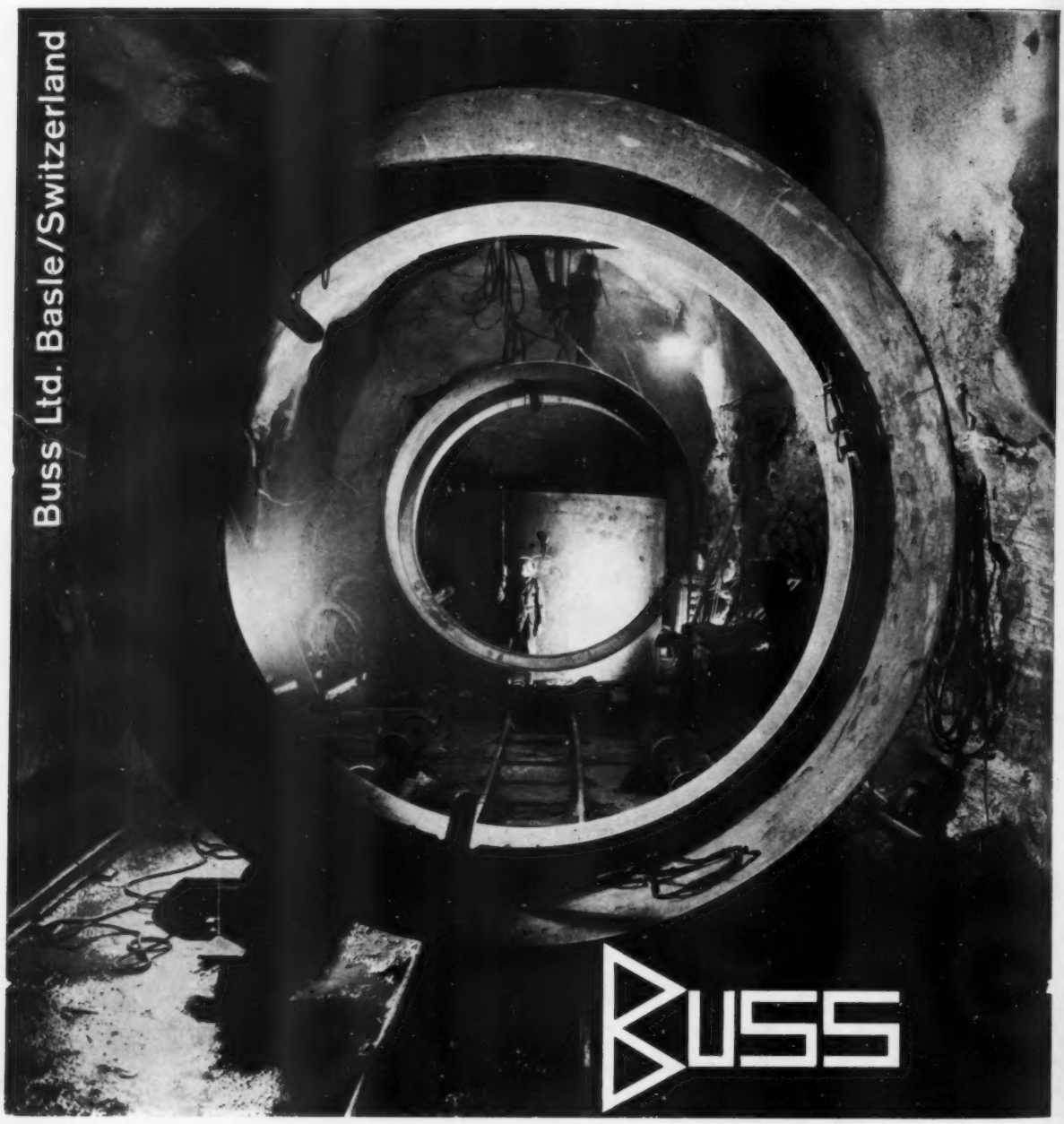

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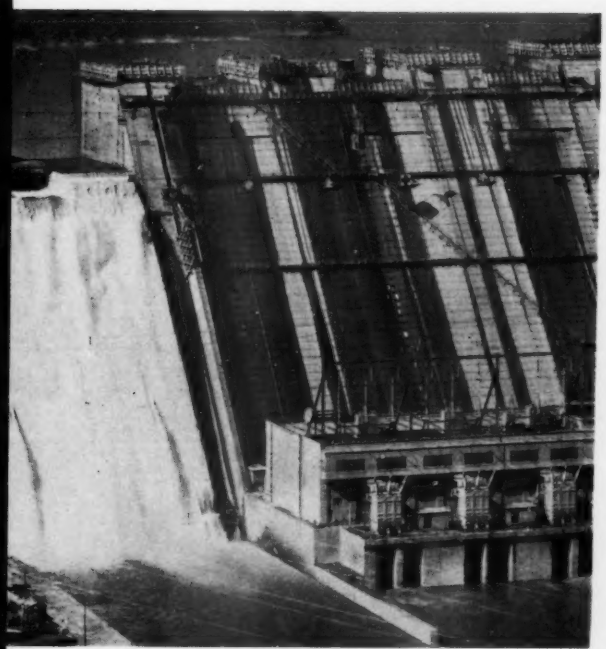

Mitsubishi Electric has again demonstrated its superiority in production capacity and technical skill by completing 3 SETS of 105,000 kVA umbrella type water-wheel generators —the largest of this type ever produced in Japan.

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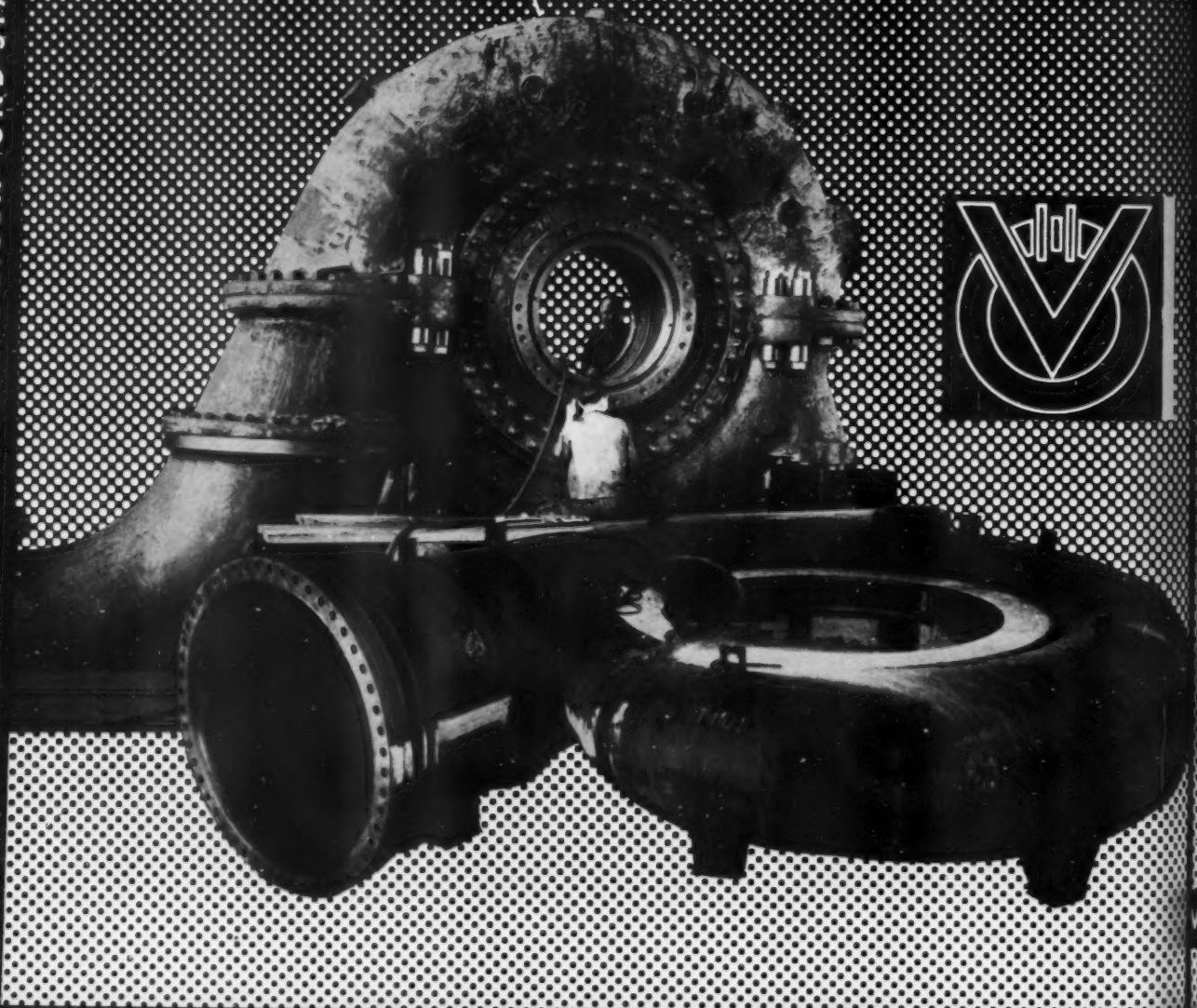

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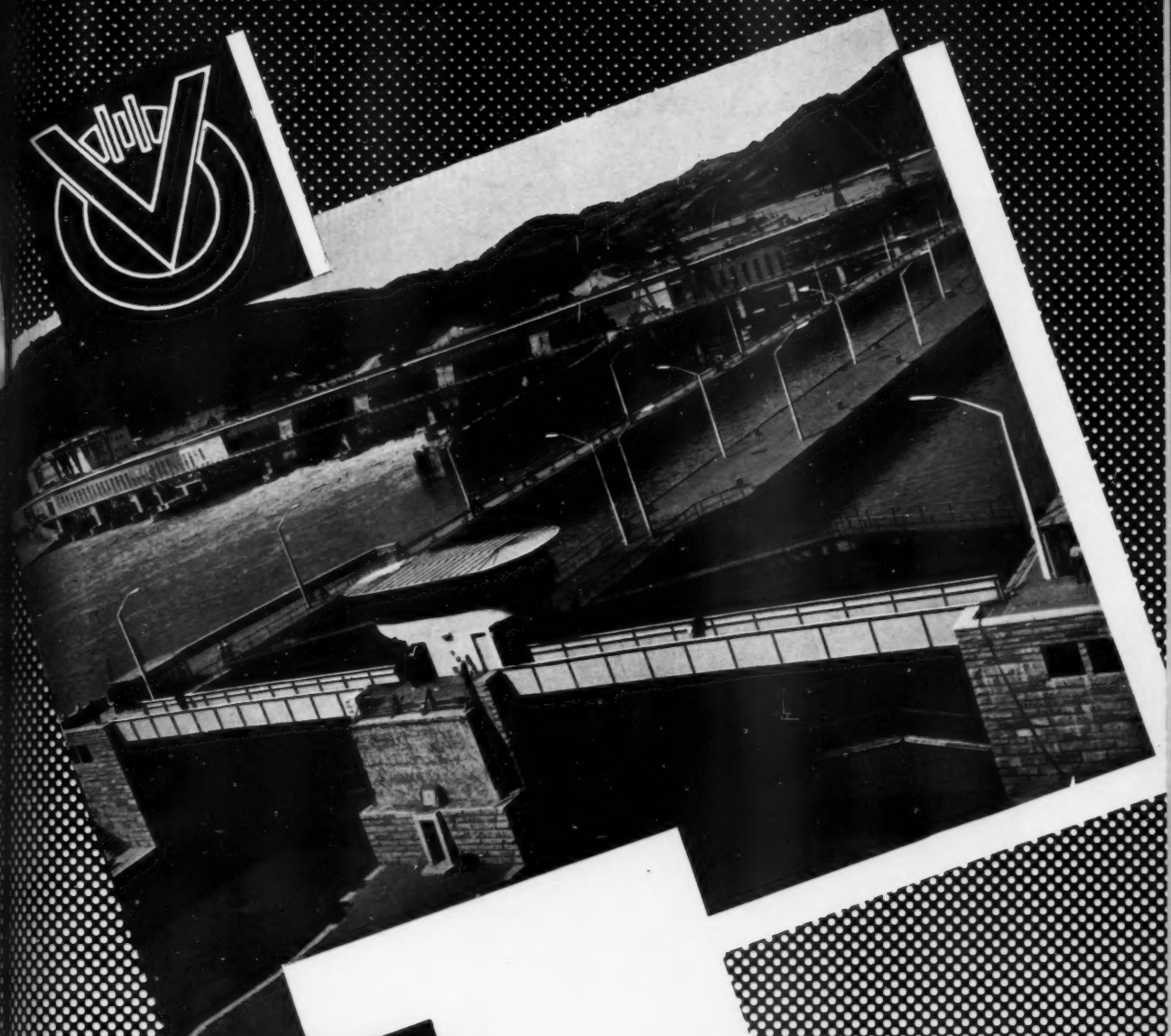

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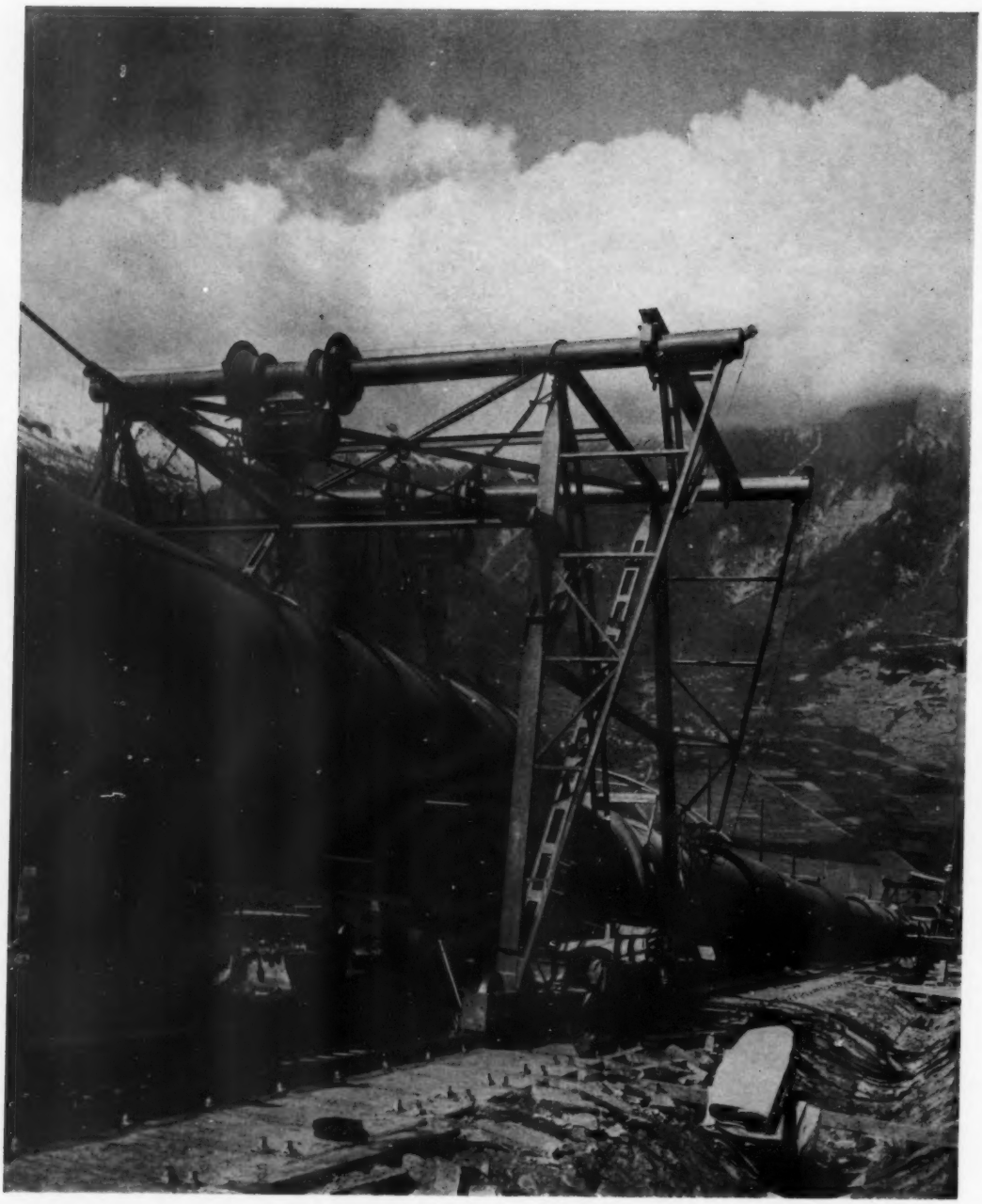

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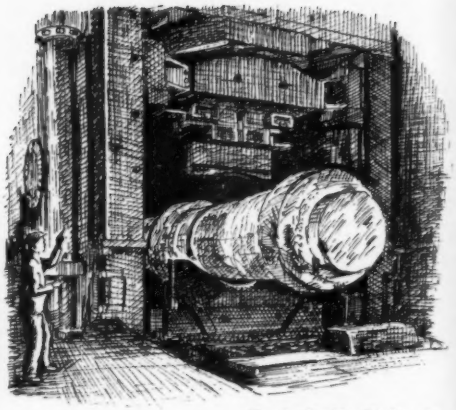
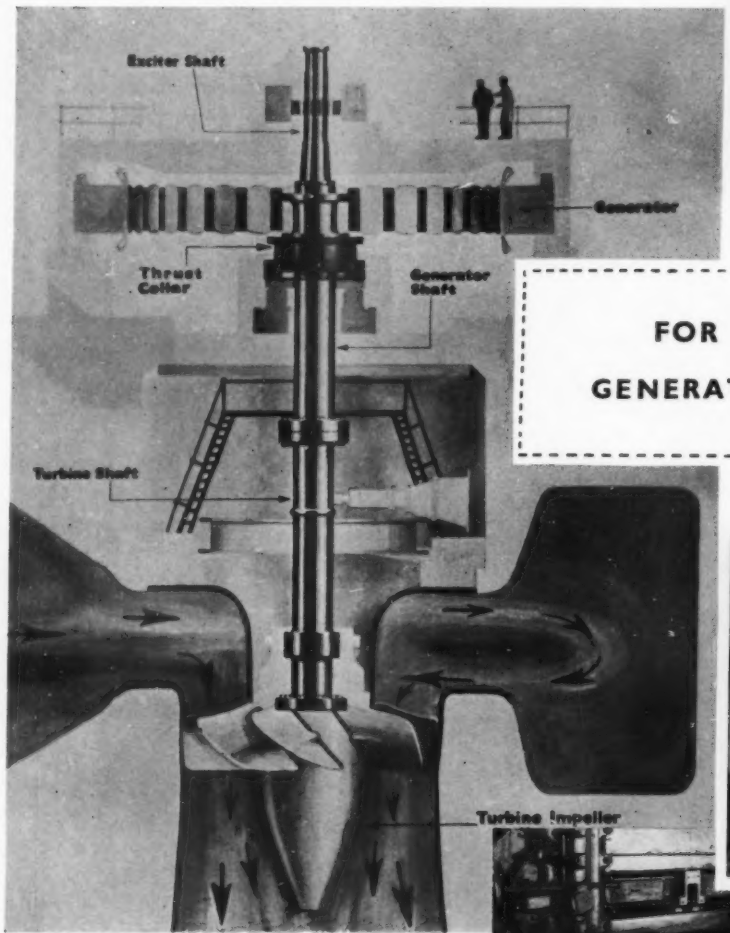


Forging Turbine Shaft under 7,000 ton Electro-hydraulic Press.



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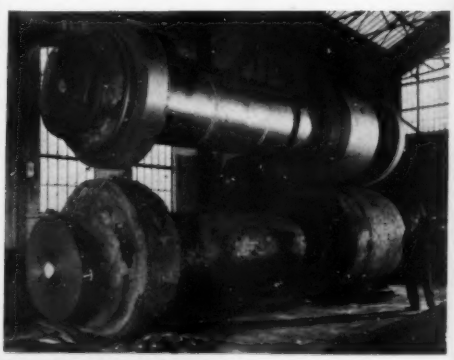

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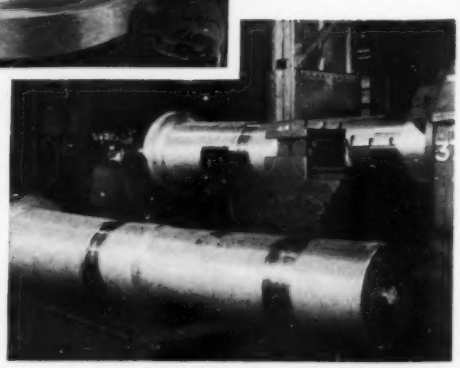

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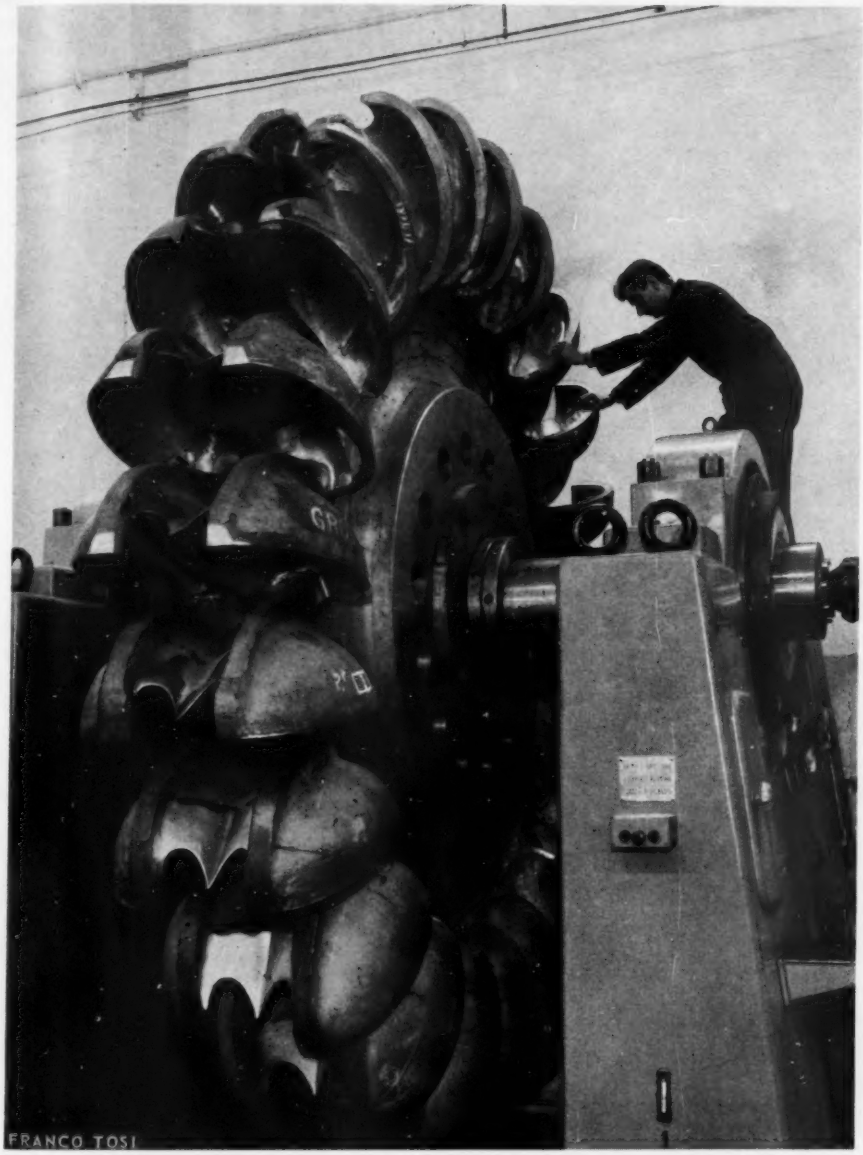

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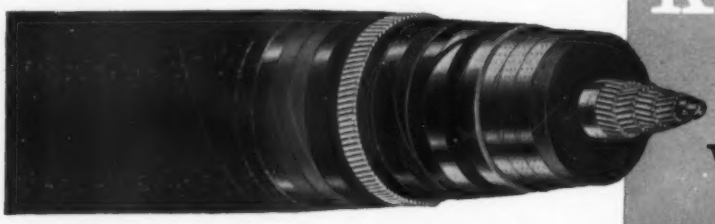

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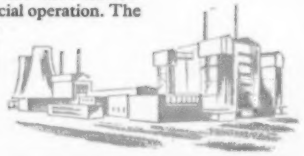

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Finland's Power Economy

A VISITOR motoring through Finland, or better still, flying over it, soon appreciates the aptness of the popular description of the country as "the land of a thousand lakes." Perhaps even more than Norway and Sweden it gives the impression of "water, water everywhere." Unfortunately for power development, this water has collected in predominantly flat country. Finnish hydro-electric stations are therefore essentially low-head developments; Kaplan turbines are the general rule, Francis turbines form a small minority, and we have not heard of a single Pelton machine in the country.

In the north of Finland the heads that can be made available are somewhat higher than in the south, as the average height of the ground ranges from 100 to 200 m., and reaches as much as 300 m. in the upper courses of some rivers. Here, however, there are fewer lakes, and the seasonal variations in river flow are extreme. On the Kemi River, for instance, the discharge during the snow melt may be five times the average flow, to be followed during the succeeding winter by a flow only one-fifth of the normal. Regulation of such rivers therefore entails the impounding of shallow reservoirs of immense area.

To add to the natural difficulties, two-thirds of Finland's water-power potential is in the north, whereas the overwhelming preponderance of population is in the south.

A recent visit we paid to Finland left us with a healthy respect for the way the Finns are tackling the problem of the country's power supply. Finland sustained a severe setback after the 1939–40 Finno-Russian war, as she had to surrender more than one-third of her hydro-electric capacity at that time. Thus in 1940 the hydro-electric output for the year was only 1,700 GWh as against 2,800 GWh in 1939. Since 1940, however, new hydro-electric capacity has enabled output to be increased at the rate of about 12% per annum. After the 1944 armistice Finland retained 415 MW of water-power plant, producing 2,500 GWh per annum; by 1955 the installed capacity passed the 1,000 MW mark and the annual production exceeded 6,000 GWh. Now, with an installed capacity of 1,500 MW and a mean output capacity of 7,500 GWh,* about half of Finland's economic water-power potential, estimated at 14,000 GWh per annum, has been developed, and it is expected that the rate of increase of hydro-electric capacity will gradually decrease to 8%, in which event the maximum of 14,000 GWh will have been developed by 1975.

Much of the future development will be on the Kemi River, which, when fully harnessed, will furnish about one-third of Finland's total hydro-electric output. Pirttikoski station, described in our March 1959 issue, is now coming into production, the first machine in Valajaskoski should be running this summer and preliminary work is in progress on Juukoski station. Other stations on the Kemi catchment are in prospect. The Oulu River is already largely harnessed, and we hope to describe these developments in due course. Finland would also receive a share of the power from the joint Scandinavian Torne-Kalix scheme, described in our February issue, if it materialises.

The transmission problem in Finland is somewhat similar to that in Sweden, for the main power-producing area, north of the Oulu, is about 500 miles from the main load centre around Helsinki. Two 400 kV transmission lines from the north to the south of the country are planned, and the first line is in an advanced stage of construction. A great deal of development work has gone into the mechanical and electrical design of these lines, and we hope to publish in due course an article on the subject specially written for us by the Chief Engineer in charge of Finland's transmission lines.

A 200 kV link with Sweden was brought into service in 1959.

With the full development of the water-power resources in sight, Finland is already studying other forms of power. At the moment, thermal plant furnishes about 40% of the country's power, and this

* Actually the hydro-electric generation in 1959 was only 5,500 GWh on account of water shortage.

proportion will inevitably increase, and is estimated to reach as much as 60% in 1970. In this respect Finland is at a disadvantage, for she has no coal, her wood is more valuable as an export in various forms than as a fuel, although a substantial amount of waste wood is burnt, and her only valuable indigenous fuel is peat, deposits of which are estimated to be equivalent to about 300 million tons of coal. For these reasons it is thought that atomic power will become economic sooner in Finland than in many other countries.

Impetus has been given to the development of thermal plant by questions of finance, which are naturally difficult in a country with such a small population. After the last war important credits were granted by the World Bank, and further assistance has been received more recently from this organisation. Internal credits have been derived mainly from the National Pensions Institute and the Post Office Savings Bank, but the facilities in this direction have been reduced by recent legislation. It has become necessary, therefore, to seek other means of financing, and the smaller capital investment entailed in the construction of steam plants is becoming a significant factor in the situation. There is no reason to suppose, however, that any fundamental change is indicated in the basic policy of developing all the country's economic water-power resources.

The water-power resources of Finland are being exploited mainly by three associated companies in which the State exercises a controlling interest, and these three companies are responsible for 85% of the country's hydro-electric capacity. The parent company is Imatran Voima Oy, in which the State of Finland holds 53% of the capital and the National Pensions Institute the remainder. The two other companies are concerned with the development of the Kemi and Oulu Rivers respectively; they are Kemijoki Oy, in which the State owns 60% of the stock and Imatran Voima Oy the remainder, and Oulujoki Oy, in which two-thirds of the stock is owned by Imatran Voima Oy and the remainder by private companies.

Valuable service both to the State companies and to municipal and private power interests is rendered by the Finnish Association for Power and Fuel Economy (EKONO) and its Construction Department, "Consulting." EKONO also forms the headquarters for the Finnish National Committee of the World Power Conference, and "Consulting" is closely connected with the Finnish Water Power Association.

Manufacturing facilities have also been developed in Finland for water turbines, gates, cranes and heavy electrical equipment.

Thus, Finland is well organised to follow a co-ordinated policy of power development, and to implement it with the aid of the necessary technical services.

Sennar Hydro-electric Project

THE £4 million Sennar hydro-electric project was inaugurated recently by a simple tape-cutting ceremony performed jointly by President General Abboud, of the Republic of the Sudan, and His Imperial Majesty Haile Selassie, Emperor of Ethiopia. The new power programme, undertaken by a consortium of The English Electric Co. Ltd. and Messrs. Siemens-Schuckertwerke, of Erlangen, involves three main tasks: the building of a hydro-electric station with two English Electric 7,500 kW Kaplan water-turbine alternator sets at the existing dam at Sennar, on the Blue Nile; the extension of the Burri power station in Khartoum by installing a new English Electric 10,000 kW steam turbo-generating set; and the erection of an overhead transmission line to connect Sennar with Khartoum, with intermediate substations at Wad Medani and Hassa Heissa.

World Power Conference, Madrid

THE next sectional meeting of the World Power Conference will take place in Madrid from 5 to 9 June, 1960. The general theme adopted for this meeting is "Methods for Solving Power Shortage Problems" and has been chosen in view of the universal desire to increase the traditional sources of power, or to replace them by others. The list of the subjects is as follows: methods of investigation of energy sources and requirements, efficiency of production and utilisation of energy, technical developments in transportation, establishments of nuclear reactors on an industrial scale, and functional inter-relation between conventional and nuclear production of energy. The first two subjects will include hydraulic energy and the working languages at this meeting will be English, French and Spanish. There will also be special tours and technical visits. A copy of the programme together with further information and application forms may be obtained through the appropriate National Committee of the World Power Conference.

Power Development in Pakistan

IRRIGATION experts of international repute arrived in Lahore for examination of the Rs. 1,400,000,000 multi-purpose Mangla dam project's design prepared by a British engineering firm. After the final check-up, the experts will submit their report to the West Pakistan Water and Power Development Authority regarding any changes to be made in the design.

In the light of the experts' recommendations, the W.A.P.D.A. will invite tenders for the construction of the project from contractors throughout the world. Construction work is expected to begin by the middle of next year. One of the biggest irrigation and power projects in the world, the Mangla dam is expected to take about eight years to complete. It will help to irrigate 3,000,000 acres of land and will have the capacity of generating 300,000 kW of electric power. The dam is of the embankment type and will have a huge capacity of permanent spillway which can take care of about 1,500,000 cusecs.

Scottish Turbo-Generator Contracts

THE North of Scotland Hydro-Electric Board have placed orders for turbo-generating plant for their power stations at Livishie, Glenmoriston, Inverness-shire, and at Loch Glashan, Loch Fyneside, Argyll.

The vertical Francis turbine for the Livishie power station, which will have a rated output of 21,200 b.h.p., will be manufactured by the Harland Engineering Co. Ltd., of Alloa, who will also supply and install the main valve and associated equipment. Associated Electrical Industries Ltd. (Heavy Plant Division) will

supply the 15,000 kW generator. The generating plant will be designed to operate by automatic control both within the station and from a remote point.

The Loch Glashan power station, which will be built near Loch Gair on Loch Fyneside, will have a horizontal Francis turbine of 8,500 b.h.p., also to be manufactured at Alloa by the Harland Engineering Co. Ltd. It will drive a 6,000 kW generator supplied by Associated Electrical Industries Ltd.

The electrical and mechanical consulting engineers for the Livishie works are Messrs. Kennedy & Donkin, and for the Loch Glashan scheme, Messrs. Strain & Robertson.

Swedish Water Turbines

THE year 1959 will be a record as regards installed KMW turbines. The total output of turbines started up during the year will amount to nearly half a million horsepower. During the months of November–December five new units will be put into service; these are Järkvissle, 60,000 h.p.; Lottefors, 9,300 h.p.; Bjurfors Nedre, 34,000 h.p.; Bergeforsen, 50,200 h.p.; and Trängslet, 140,000 h.p. All these stations are situated in Sweden.

The first Järkvissle turbine was commissioned on September 25. During December the second unit was put into service, as already mentioned, thus completing the last power plant on Sweden's most exploited river, the Indal. The two units at Järkvissle, which will be remotely controlled from Stadsforsen, a station about 13 miles to the north, are estimated to have an annual production of 360 million kWh.

1960 Water Conference, Colombo

A CONFERENCE is to be held in Colombo, Ceylon, from 5 to 13 December 1960 to discuss the current problems in water resources development in the Far East. The topics on the provisional agenda include the development of multi-purpose projects embracing flood control, hydro-electricity and irrition; organisation for the planning, design and construction of river and valley projects, and the general utilisation of the water potential of the countries in the region. The programme is being organised by the United Nations' Economic Commission for Asia and the Far East, Bangkok, Thailand.

Proposed Survey of Niger Dam

THE United Nations' recent announcement that it plans to spend $1,000,000 to study the feasibility of a multi-purpose dam on the Niger river has given new impetus to obtaining cheap electricity. The Western Regional Government in 1958 granted the Electricity Corporation of Nigeria an interest-free loan of £1·3 million. This loan was to finance new electrical generating projects in the Region with a completion target date set for 1962.

By then it is estimated that 28% of Western Nigeria's population will have access to electricity with a peak generating capacity of approximately 30 MW. The Western Region launched its electrification programme two years ago without the certainty that the Niger dam would ever be built or, for that matter, even surveyed to determine whether such a vast project was feasible. However, the Regional Government encouraged the Electricity Corporation of Nigeria to set aside £1,000,000 for future electrical development within Western Nigeria on the assumption that cheap electricity would be available from the Niger by the end of the Financial Year 1964-65.

Meanwhile, the Region is going ahead with its own plans to bring power to its smaller towns and rural areas. Within the next five years, the Western Nigerian Government plans to spend an additional £250,000 to bring this about. Already the Electricity Corporation of Nigeria is conducting pilot schemes at the towns of Badagry and Ijero and the findings from these two experimental projects will be used to guide the Western Region in future electrification plans.

Correspondence

Norway's Hydro-Electric Power and Industries

To the Editor, WATER POWER

I was very interested in the article "Norway's Hydro-Electric Power and Industries," as it paints an excellent picture of Norway's efforts to develop its water power to supply everyday requirements and industry.

During the past 20 years, the State and the municipalities have had a virtual monopoly in the power development programme. Industries have more and more become hirers of power, and obstacles have been put in the way of the development of private power sources—sources well suited for this purpose. Now that Norway is joining the Outer Seven common market there will be a change in this situation, and presumably capital will become more accessible and various restrictions will disappear.

Concerning the competition between atomic power and other sources of energy, I think that Norwegian water power will remain competitive beyond 1990, and will continue to be advantageous even if we reach a development level of 100 milliard kWh per annum. Norsk Hydro have now completed Rjukan IV at a cost of kr. 2,500 per kW, which means approximately 3 öre per kWh. This plant is now operating in parallel with other large plants with low operational costs, and the average cost for water power is less than 1·5 öre, possibly only 1 öre per kWh.

Of the three provinces in Western Norway—Sogn og Fjordane north of Bergen, Hordaland around Bergen, and Rogaland around Stavanger—Sogn og Fjordane possesses the most power and the largest power plants, and electricity from this province is very cheap in relation to the value of the krone today.

In all probability, Norwegian water power will hold its own in competition with atomic power even beyond the year 2000.

A. MOLLØ-CHRISTENSEN, M.N.I.F., M.R.I.F.
Consulting Engineer.

Eiksmarka,
Norway.

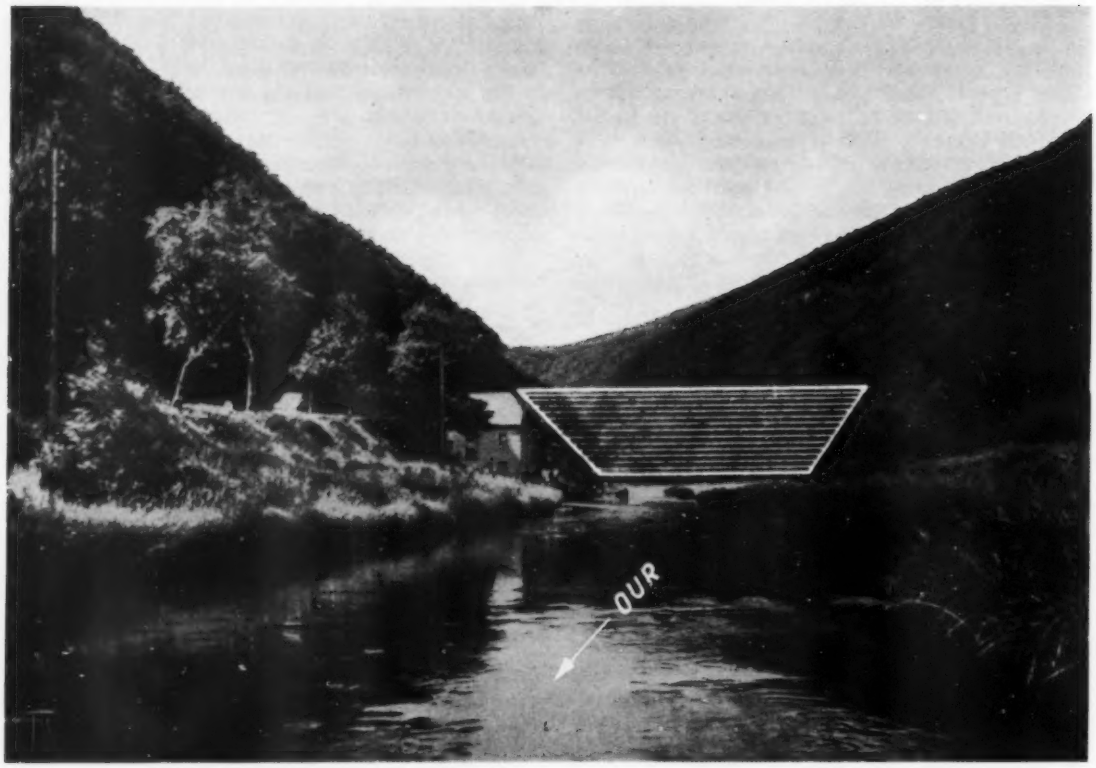


Fig. 1. View of the site of the lower dam at Lohmühle

The Vianden Development

A short description of a 640 MW pumped-storage project, on the north-east frontier of Luxembourg, and particularly designed for the supply of peak-load energy to the centres of heavy industry in Germany

ALTHOUGH hydro-electric resources are by no means confined to mountainous territory, it is unlikely that the average engineer would think of the Grand Duchy of Luxembourg as being a potential producer of hydro-electric energy. Apart from the Moselle, the country has few rivers, an area of only 1,000 sq. miles and a population of approximately 300,000 but the industrial and economic importance of this ancient state is out of all proportion to its size. The grand duchy of Europe, Luxembourg, consists mainly of the upper basins of the Sauer and its tributary the Alzette, both of which drain and dissect the south-east flank of the Ardennes. A province known as Luxemburg forms the Ardennes highland in Belgium and the two together, with certain other smaller areas, constitute the Luxemburg state of ancient times.

Thermal plant and imported power have always satisfied the needs of the prosperous industrial centres situated in the south of the country where the iron industry has been established for many generations. Other industries include leather tanning, slates, metal construction, porcelain, explosives, gloves, drapery and cement; the local demand for energy is increasing at the same rate as in most other countries, and although various projects have been evolved in the past, it is only comparatively recently that it has been economically feasible to develop part of the country's hydro-electric resources.

The eastern frontier between Luxembourg and Germany is entirely formed by the rivers Our, Sûre and Moselle, the confluence of the former two being some miles north of the famous and ancient town of Echternach, and of the latter two at Wasserbillig. Of these rivers, the Our and the Sûre are particularly suitable for development, and two projects are now in the course of realisation, at Esch-sur-Sûre and Rosport, both on the river Sûre. A further, much larger

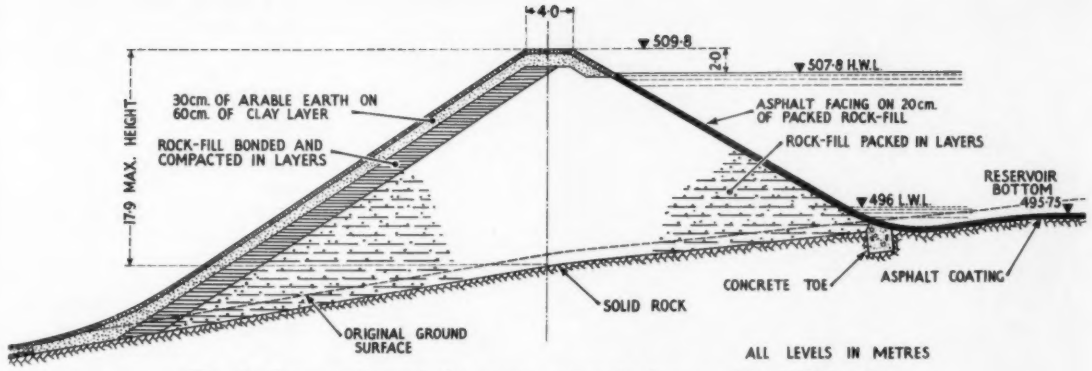


Fig. 2. Cross-section of the upper reservoir dam on Mt. Nikolausberg

development, predominantly pumped-storage, on the river Our is now in an advanced state of planning, and although major constructional work on the site has not yet begun, the type, size and economic importance of this project make it of great topical interest to hydro-electric engineers.

The Our flows through a deep valley flanked on either side by steep slopes which rise to a plateau about 300 m. above the river. Preliminary surveys carried out over twenty years ago showed that the valley would be suitable for development, but, in view of the geographical situation and political difficulties which intervened, it was only eight years ago that this international project became probable rather than possible. The Societé Electrique de L'Our (S.E.O.) was founded in 1951 on the initiative of the Luxembourg Government and with a widely distributed share capital, to complete final plans for the Our valley hydro-electric scheme, and, as a result, it has been decided that the main dam will be situated at Vianden, near Mount Nikolausberg.

Although Luxembourg has been linked to Belgium

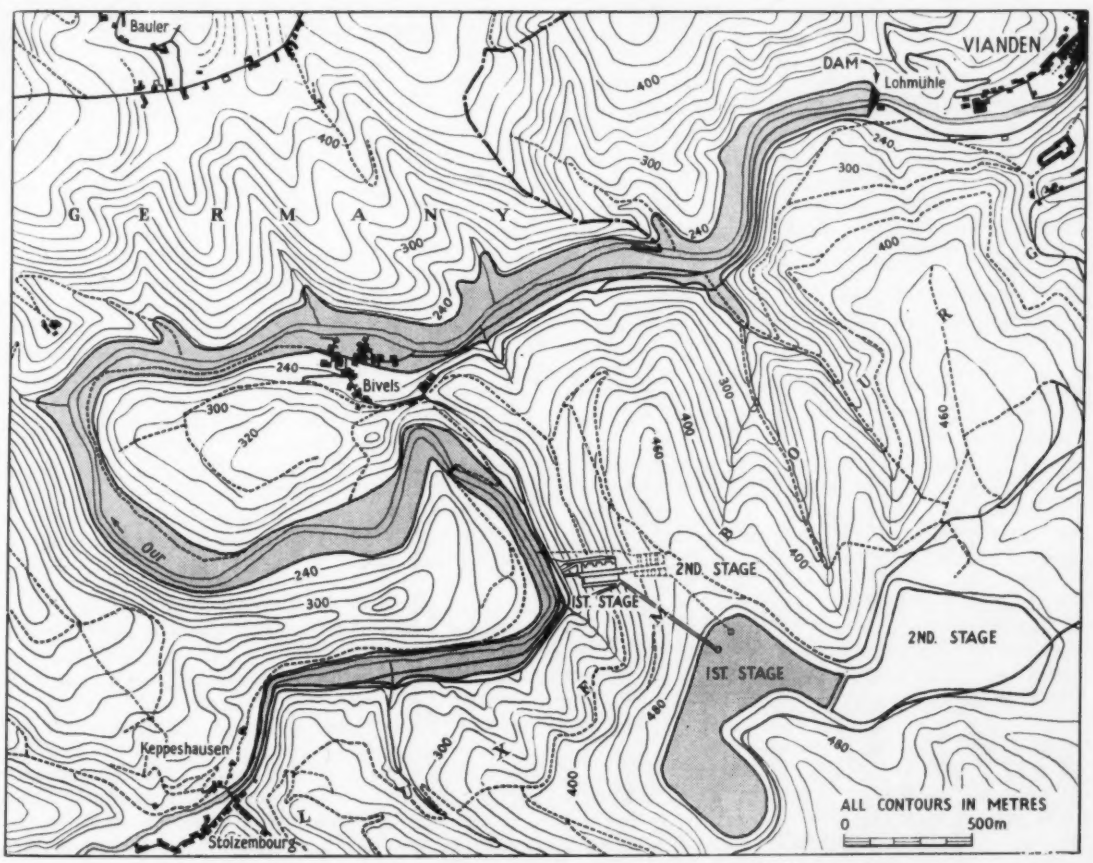


Fig. 3. The locality and general layout of the dam and reservoirs

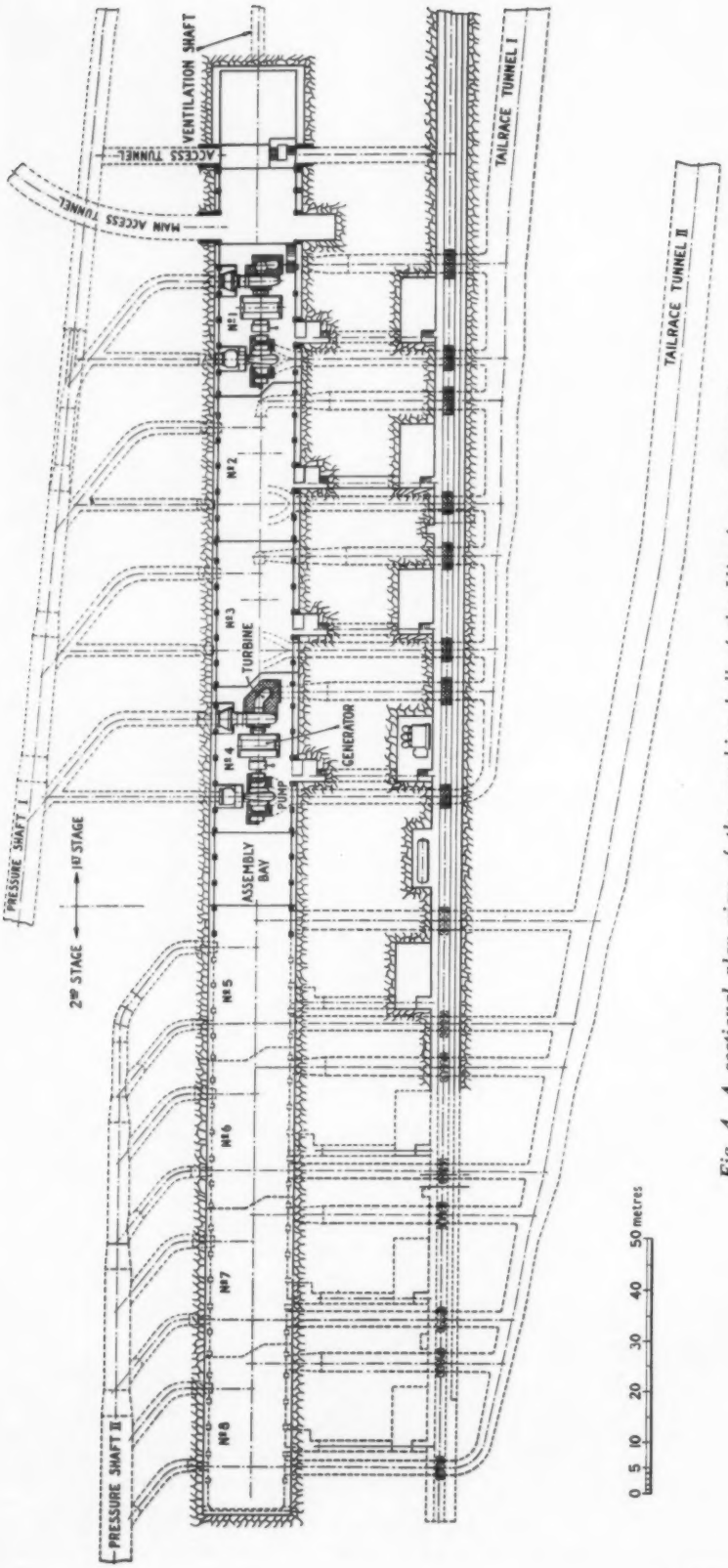


Fig. 4. A sectional plan view of the machine hall of the Vianden power station

by a customs union since May 1922, the country is completely autonomous in all other respects and any major development in the territory must have a very marked economic advantage. Vianden is ideally situated in the heart of an immense area delimited by the Ruhr, Borinage, Campine, Lorraine and the Saar; existing or projected run-of-river power stations in the Rhine valley and thermal power already cater for the energy requirements of German industry but there has long been a need for a major pumped-storage scheme to supplement existing resources. Vianden is therefore intended to satisfy peak-load demand by pumped-storage during off-peak hours and, when both stages are complete, this as yet practically unknown project will probably have an installed capacity of 640 MW which will make it the largest pumped-storage hydro-electric development in the world.

Past experience with similar types of plant has shown that the overall operating efficiency at Vianden will be approximately 66%. The upper reservoir will be formed by building an earth dam on the crest of Mount Nikolausberg, about 300 m. above the lower reservoir. A penstock will connect it to an underground power station from which a tailrace tunnel will lead to the lower reservoir, created by a dam built across the Our at Lohmühle between Vianden and Stolzembourg. Extensive geological surveys have shown that the range of hills, of which Mount Nikolausberg is part, contains good-quality schist and quartzitic sandstone and it is for this reason that an underground power station is feasible. Although initially the project provides for a total output of 320 MW only, the final stage will consist of doubling the capacity of the upper reservoir and installing additional plant to increase the output to about 640 MW.

During the first stage, energy consumption for pumped-storage will be 215,000 kW with a

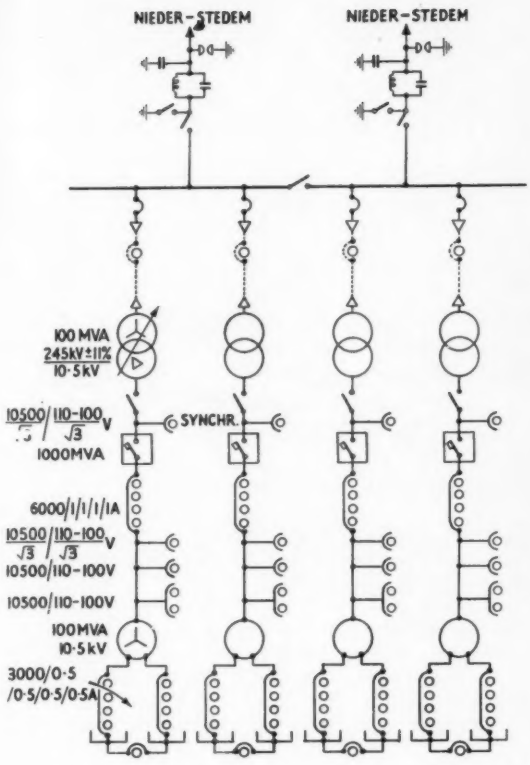


Fig. 5. Circuit diagram of power station

daily operating cycle of 9 hours pumping and 4 hours generation or, in other words, 3,060 hours pumping and 1,360 hours generation per annum. Annual production of peak-load energy will be 435 million kWh and the corresponding figure for pumped-storage consumption will be 660 million kWh with a gross mean operating efficiency of 66%. The gross mean head will be 280 m. and the turbines have been designed for a nominal discharge of 144 cu. m. per sec., the pump delivery being 64 cu. m. per sec.

The upper storage reservoir is formed by a rockfill dam built round the plateau. In the initial stage, this dam will be no less than 2·3 km. long and the average height will be 14·3 m., resulting in a storage capacity of 2,900,000 cu. m. with a fluctuation in level of about 12 m. When the second stage is completed, the storage capacity will be approximately doubled by extending the dam as shown by the hatched section on Fig. 6. A bituminous asphalt layer will make the upstream face of the dam and the reservoir bed impervious. The rockfill will consist of compressed schist obtained when the reservoir is excavated, and it is expected that the total volume of such material required will be about one million cu. m.

As shown in Fig. 7, the penstock will be a vertical pressure shaft, 570 m. long with an internal diameter of 6·2 m., followed by a section inclined at about 60% and a horizontal section leading to the branch pipe. All parts of the penstock will be concreted but no steel linings are at present envisaged.

Vianden underground power station will be

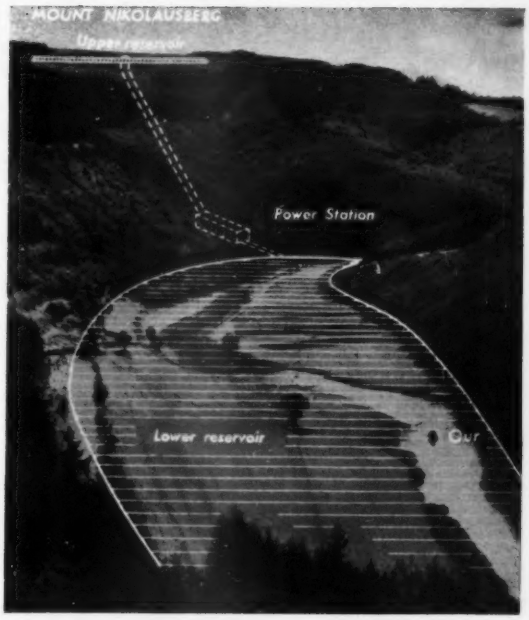


Fig. 6. View of power station site

equipped, initially, with four horizontal-shaft units. each comprising a 53,750 kW pump, a 100,000 kW alternator, and an 80,000 kW turbine. The station itself will be 175 m. long and 16 m. wide with a maximum height of 19 m., thus allowing adequate space for the installation of four further units when the second stage of the development is undertaken. The turbines, which are designed to operate at 428 r.p.m., will run free during pumping. Each pump will also be connected to a small auxiliary turbine through a special coupling, thus allowing the almost instantaneous changeover from generation to pumping or vice versa.

The generators, which will be equipped with closed-circuit cooling, will each be connected to a step-up transformer raising the voltage to 220 kV. The transformers will be installed in a separate chamber, from which 220 kV cables lead to the outside transformer bay and switching station at ground level. A high-voltage transmission line will connect Vianden power station to the grid of the Rheinisch-Westfälisches Elektrizitätswerk A.G.

The lower reservoir at Lohmühle, about 1 km. upstream from the Vianden bridge, will have a maximum height of 25 m. and a crest length of 100 m. The reservoir formed will be some 8 km. long, and, when the final stage is completed, 4,600,000 cu. m. of water will be available. A small compensation set will be installed at the foot of the Lohmühle dam with the dual function of regulating the downstream flow and providing power for the auxiliary services throughout the development.

Energy produced at Vianden will be disposed of through a variety of somewhat unusual channels; situated in a country which may well never consume any of the energy it produces, this development probably has a more international character than any other hydro-electric scheme in the world. German

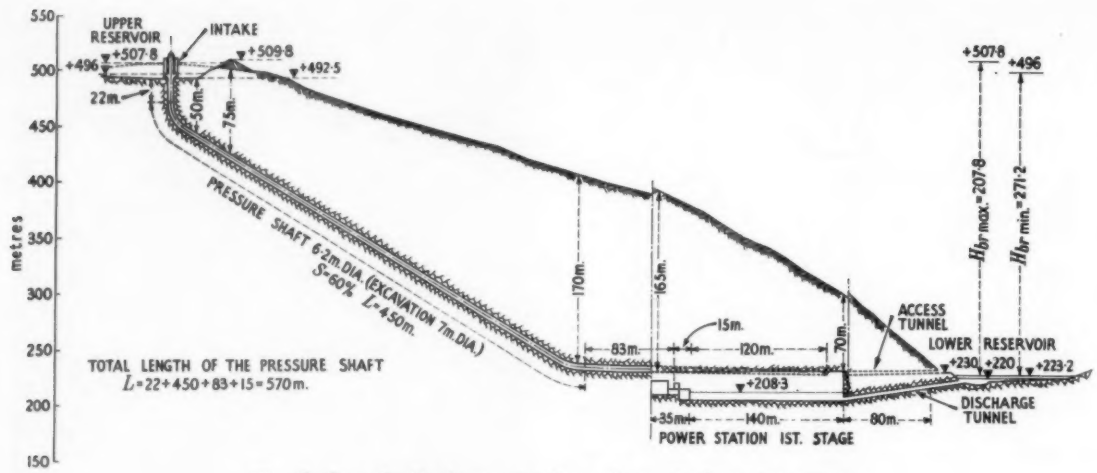


Fig. 7. Longitudinal cross-section of penstock arrangement

industry may often be the only consumer but Vianden power will be available to other nations through the European grid. During normal pumped-storage operation, the S.E.O. will buy energy from neighbouring networks but one or more units in the power station may subsequently be leased to specific customers at a fixed annual fee. Similarly, a barter system is also envisaged, whereby the S.E.O. will receive free power and will then return a percentage of the peak-load energy produced, retaining the balance for sale. These various operating procedures can be combined if necessary but the method employed will depend on the conditions prevailing in the power systems which will be directly affected by the Vianden development.

The advent of the Common Market and the much increased collaboration in Europe in recent years have helped to make Vianden a practical proposition and this journal hopes that it will have occasion to publish a more detailed description when the project becomes a reality.

Line Material and Substation Accessories. This handsome catalogue, well bound and illustrated, has been issued by Società Elettro-Morsetterie Volpato, Milano, Italy, and brings the list of this firm's specialities up to date. The last catalogue was sent out ten years ago and enquiries are now invited for complete equipment to be supplied for overhead lines or underground wiring. The catalogue contains 457 pages and all important components are given in both Italian and English. The company seeks to be regarded as a collaborator rather than a mere supplier of material and asks to be allowed to decide which are the most suitable accessories to be supplied in each case.

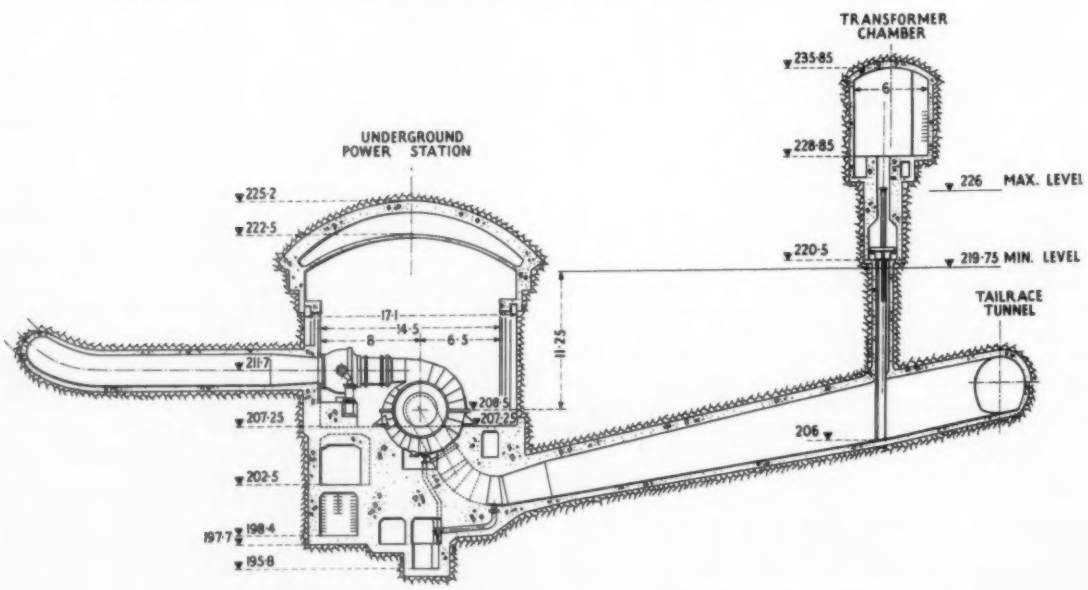


Fig. 8. Vertical cross-section of the underground power station

Comparison of Flow-Measuring Techniques at Kinlochleven Hydro-Electric Station

This article describes field tests in which various methods of flow measurement were compared in a 40 in. pipeline. Advanced versions of the current-meter, pitot-tube, salt-velocity and salt-dilution techniques of gauging the flow were investigated and a comparison made of the systematic and random errors, the convenience of the various methods, and the man-hours required in each case*

By F. A. L. WINTERNITZ, Dr.Techn., Dipl-Ing.E.T.H., V.D.I., A.M.I.Mech.E., A.F.R.Ae.S.

THE development of improved versions of accepted standard methods for metering large rates of flow is a major research objective at the National Engineering Laboratory. Considerable effort has been devoted to establishing techniques and developing equipment giving higher accuracy of measurement than at present attainable together with greater convenience of use. The laboratory facilities at East Kilbride available for these investigations included a pipeline of 20 in. diameter, whereby flow rates up to 20 cusecs could be determined with high accuracy by means of a weighing tank.[1] Since the apparatus and methods thus investigated were primarily intended for field application, it had been an early decision to include in the detailed programme comparative flow measurements in a hydro-electric power station as soon as the development work had passed the laboratory phase. Accordingly, preliminary proving tests were carried out in June, 1957, at the Kinlochleven power station[2, 3] of the British Aluminium Company; these have been fully described in reference 4†. The eventual choice of the Kinlochleven power station of the British Aluminium Company was dictated by a number of features not found elsewhere:

(1) The Pelton units of the station are supplied by six pipelines which feed into two bus pipes at the bottom of the pipe track. Access to a single pipe is possible without change in plant load since the total flow can be redistributed over the remaining pipes. As up to two lines can be taken out of operation, this affords a means of increasing the rate of flow in two steps during tests if required.

(2) The pipeline is 1¼ miles long and includes straight lengths of up to 1,000 ft. Although access into the pipe is limited, special sleeve positions are provided for the purpose, stations for the different methods could be sited to ensure interference-free operation. With a pressure of approximately 400 lb. per sq. in. at the bottom of the line, it was possible to test the equipment under high pressure.

(3) The plant load is exceptionally steady since the electric energy generated is used for the production of aluminium.

(4) Access to the penstock is relatively easy and the British Aluminium Company was prepared to provide the necessary tappings and bosses for mounting of instruments and equipment.

A profile of the pipe track, showing the locations of the various flow-measuring stations, is given in Fig. 1.

The preliminary measurements, similar to the final ones but for the number of metering stations, established the reliability of the equipment used. They also served as a phase-by-phase check on the correctness of the planning and the suitability of the preparations which preceded the actual tests. Current-meter, salt-velocity and salt-dilution methods were compared at flow rates of 60 and 70 cusecs respectively in a pipe line of 1 m. diameter. A station was completely prepared for the pitot-tube method which, however, was not operational due to manometer failure under the high line pressure.

Briefly summarised, the conclusions from these initial tests were that:

(1) The current-meter method required less man-hours for installation and evaluation than either the salt-velocity or the salt-dilution method, if no account was taken of the time required for the rating of the meters prior to the field tests; less equipment had to be carried and it was also the most convenient method in use while giving the most consistent results. The meters, although submerged for more than 100 hours in contaminated water, nevertheless functioned satisfactorily under a line pressure of approximately 370 lb. per sq. in.

(2) The salt-velocity apparatus operated satisfactorily, mean results agreeing within 1% of the current-meter values.

(3) The salt-dilution equipment was the least developed of all methods, and although basically the simplest technique, gave results which deviated from the current-meter readings by as much as 6% in the worst case.

Results summarising these preliminary tests are shown in Fig. 2 as percentage deviations from the current-meter values.

* This article is a summary of Fluids Report No. 65 issued by the National Engineering Laboratory, East Kilbride, and relates to a final series of tests carried out at Kinlochleven. Reference is made to Fluids Report No. 59, which describes the preliminary tests carried out at the same power station.

† Frequent reference is made to this report and for convenience the abbreviation F.R.59 will be used throughout.

Methods and Equipment Used

In the final tests measurements were carried out simultaneously with pitot tubes and current meters, which yield flow rates by integration of point-velocity measurements, and by use of the salt-velocity and salt-dilution methods which yield the bulk flow directly. Given equivalent accuracy and comparable facility in operation, and neglecting overriding aspects of site and test requirements, the point-velocity techniques would be used if additional information about the flow formation is wanted, to be replaced by the bulk methods if flow rates only are wanted. In practice, however, no such clear division is possible, and for this reason the development of all four methods had been equally stressed. On the strength of the initial experience at Kinlochleven, some of the equipment was redesigned, evaluation techniques improved in further laboratory tests, and the plans for the final field measurements laid accordingly.

CURRENT METERS

Thirteen small current meters of Ott manufacture were used in the preliminary tests, having a propeller diameter of 50 mm., a nominal hydraulic pitch of 250 mm., and electric contact after each revolution. A second current-meter station was in operation during the final tests, equipped with five standard-sized[5] current meters; of these, four were of Ott manufacture, with a propeller diameter of 125 mm. and a nominal hydraulic pitch of 500 mm. A special gear train, supplied by the makers, was fitted to each meter for electric contact after each revolution. The fifth, an Amsler current meter, had been completely rebuilt for generation of sixty pulses per revolution using a semi-conductor photocell circuit suitably triggered by the propeller shaft. This was an experimental, previously untried and uncalibrated meter arrangement, developed for the study of velocity fluctuations which cannot normally be recorded in current meter measurements.

The use of the small current meters was dictated by the pipeline diameter of 1 m., which was too small to accommodate an adequate number of standard sized meters in interference-free positions. The pipeline diameter was thus less than the smallest permissible one specified by the power test code[5]; it has been pointed out[4] that acceptance of the small current meters for field use, on the strength of their successful performance at Kinlochleven and elsewhere[6, 7], would make it possible to relax this restriction.

In the case of the small Ott meters, the number was in accordance with power test code specifications[5, 8]. Their arrangement in the plane of measurement, Fig. 3, however, conformed to positions determined by use of a new pipe-flow integration technique[4] which, from the readings of the eight meters on the outer and inner ring only, allowed speedy evaluation by numerical methods. The meter recordings from all three rings and the centreline meter were used in graphical integrations, carried out for selected tests as evidence of the accuracy of the log. linear method of flow integration. The latter has since been firmly established by more direct means, showing the numerical method of evaluation to be superior to the graphical one.[10, 11] An advanced numerical method of evaluation since developed,[12] speedier still than the log. linear ones, was also employed. For a discussion of the principle underlying the current-meter method of flow measurement, see reference 4 or, for more details, reference 13.

The four standard-sized Ott meters were arranged on one radius at a distance of $0{\cdot}112D$ from the pipe wall, specified by the log. linear method as the position where in fully developed pipe flow the mean velocity is metered.[9] Experimental evidence for the correctness of such results was available from measurements with small Ott current meters in a 20

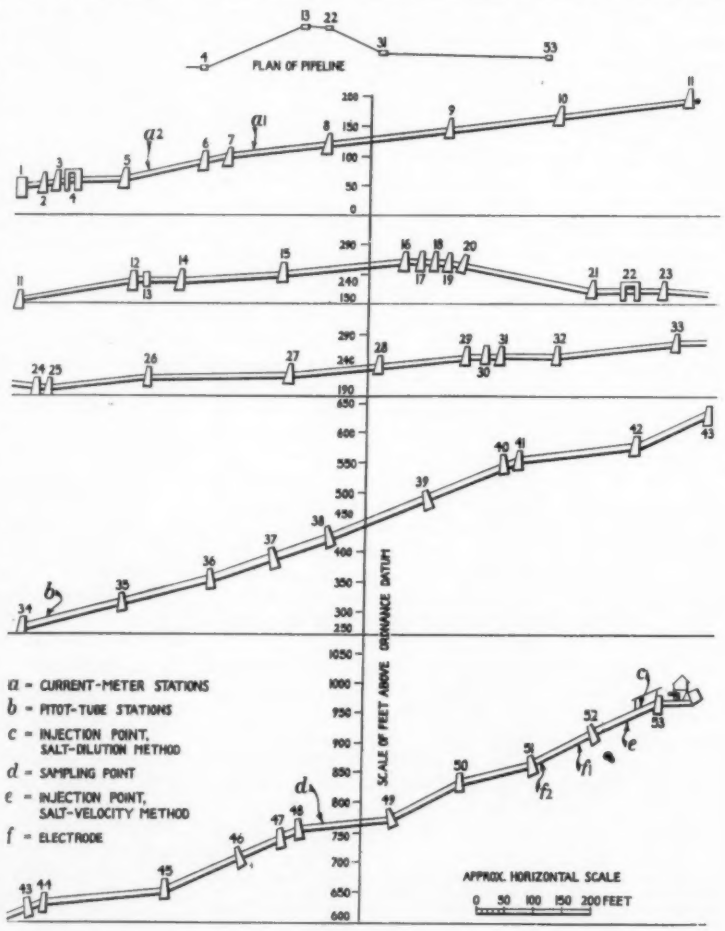

PLAN OF PIPELINE
a = CURRENT-METER STATIONS
b = PITOT-TUBE STATIONS
c = INJECTION POINT, SALT-DILUTION METHOD
d = SAMPLING POINT
e = INJECTION POINT, SALT-VELOCITY METHOD
f = ELECTRODE
SCALE OF FEET ABOVE ORDNANCE DATUM
APPROX. HORIZONTAL SCALE
0 50 100 150 200 FEET

Fig. 1. Pipe-track profile showing flow-measuring stations

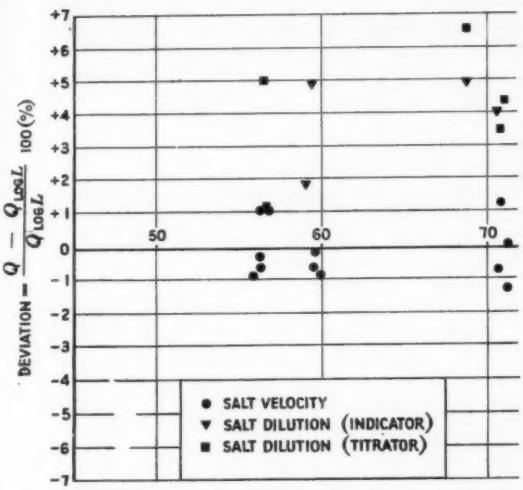


Fig. 2. Summarised results of preliminary tests

in. pipeline.[14] It was of interest to compare the performance of the standard-sized meters at this near-wall position, and thus in a velocity gradient, with that of the smaller meters at the first station; this was purely an experimental study, extended in scope by the use of the modified Amsler meter at centreline position.

All meters, with the exception of the Amsler meter, were carefully rated before and after the field tests by simultaneous calibration of up to thirteen meters[14] and close agreement was found between the two calibrations. The difference in the evaluation of randomly selected field tests was less than 0·1%.

A battery-operated automatic N.E.L. recording gear[4, 15] was again in continuous operation during the final tests.

Pitot Tubes

The integration of point velocities measured by pressure probes of the pitot-tube type is the oldest of the established metering techniques; relevant details, with particular emphasis on pipe-flow measurements may be found in references 16 and 17. If properly used, such instruments are reliable and accurate, but are subject to restrictions which may limit the practicable range, in particular if pitot traverses are to be carried out in large pipes at high velocities of flow.[18, 19]

Readings were taken on one or two diameters in the same angular location as the arms of the support cross at the current-meter station. The selection of the eight traverse points per diameter again conformed to the specifications of the log. linear method of pipe-flow integration.[9] Additional measurements were carried out at the centreline position and at the four points with distance 0·112*D* from the pipe wall; the latter were thus identical to the gauging positions at the second current-meter station.

Salt Velocity

The N.E.L. cartridge-powered injection valve and firing breech* which operated faultlessly during a firing sequence of approximately 120 single shots in the initial tests, gave an equally satisfactory performance during the final measurements where a total of 206 shots was fired.

The electrodes [Fig. 7, F.R.59], designed on the strength of laboratory experience for robustness, ease of installation and minimum flow disturbance, were again linked to separate a.c. bridge systems which registered the out-of-balance signals produced by the passage of the injected solution past the electrodes. The advantages of this arrangement developed by Young and colleagues[23, 24] are:

High sensitivity.

Zero level independent of main stream conductivity.

No polarisation effects.

No interference between the pairs of electrodes.

The bridge units, designed and built by the Division's Instrument Group, were 10 kc/s battery-operated transistor oscillator-detector units, the time signal being supplied by a transistor crystal frequency standard run on 30 V batteries.[25] Simultaneous records were taken on a mains-operated oscillograph by filming and on a battery-operated two-channel high-speed pen recorder, the latter being mainly used to check the wave form of the record. If required, the salt-velocity equipment could have been entirely operated from batteries.

Evaluation of the oscillograph records was carried out in two different ways: in the one case, the time of passage between the electrodes was determined as the distance between the centres of gravity of two consecutive traces, for which a numerical method of computation was used; this is here referred to as the "centre of gravity" method. In the other, the mid-points of horizontal lines joining those points on the traces where the ordinates were half the peak values were used to determine the time of passage, here called the "mean amplitude" method. Full details may be found in reference 24.

Leslie and Hunter[26] proposed and built equipment suitable for automatic determination of the time of passage between electrodes, which was tested in both the laboratory and the Kinlochleven tests. Based on

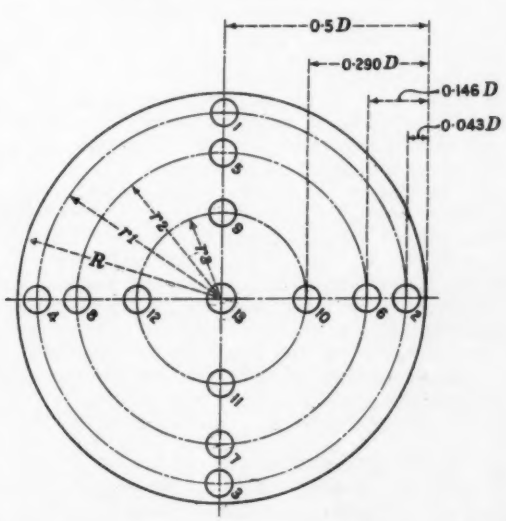


Fig. 3. Meter arrangement in plane of measurement

* *See* F.R.59 and also Water Power, January 1959, p. 11.

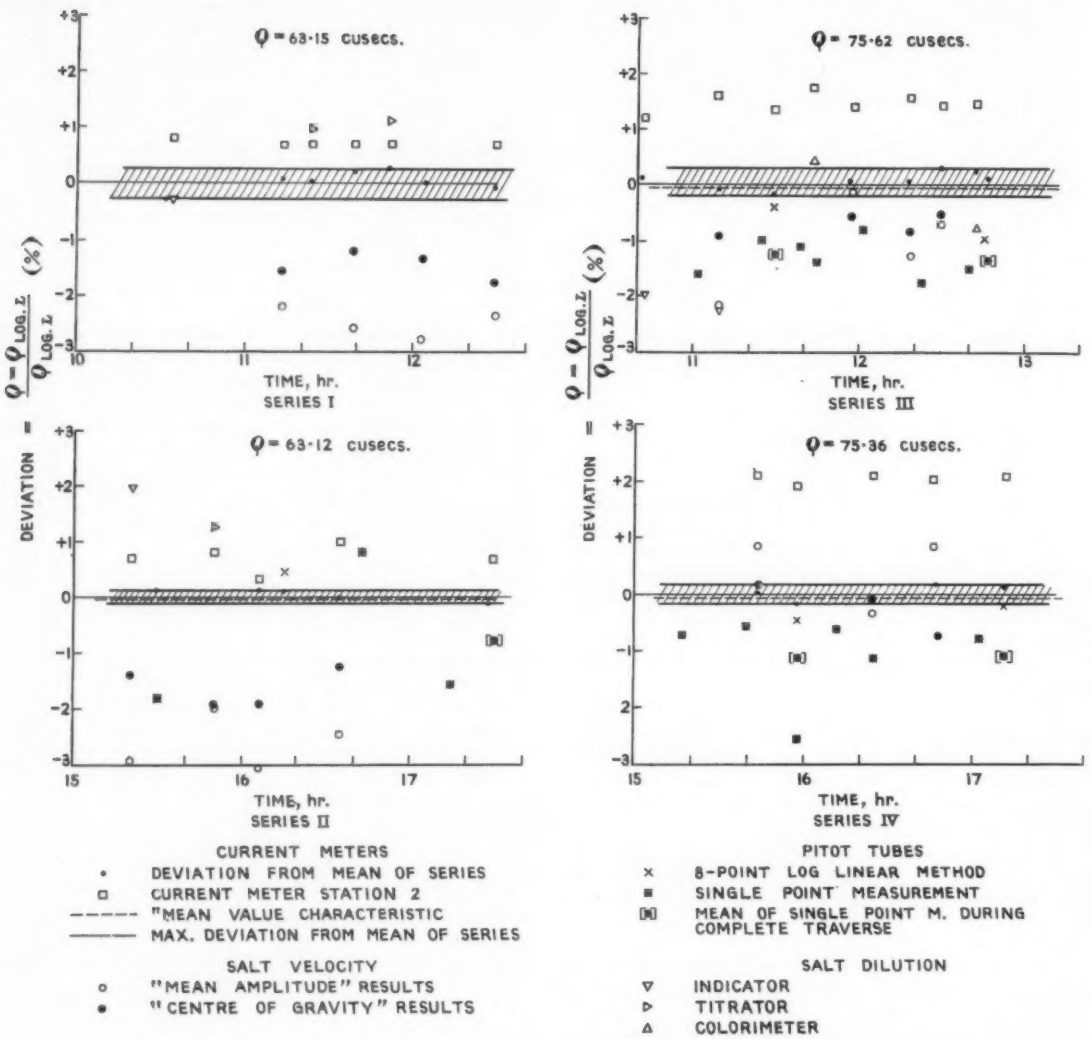


Fig. 4. The consistency of current-meter results for various flow measurements

the "mean amplitude" method described by Young and Wilson,[24] who adopted the technique for manual evaluation, it is capable of giving instantaneous answers since no storage of information is required.

In the field tests, some initial difficulties were experienced during the setting-up phase of this equipment. During the final sequences of these tests, the error and scatter of the instantaneous results were comparable to those obtained in the normal way. The result in each test was available once the salt cloud passed the second electrode, and hence progress could be checked at any given moment. Should these first promising findings be confirmed, the automatic salt-velocity apparatus would constitute a marked advance over any other equipment in use today.

Salt Dilution

The principle of the method, for a detailed account see reference 27†, is the determination of the rate of flow from the injection of a chemical solution into the stream at a known uniform rate and the comparison of the concentrations of the solution and samples withdrawn far enough downstream for complete mixing to have taken place. A major attraction of this method is that no volumetric measurements in the pipe are required.

Careful study of the results from the initial Kinlochleven tests and further analysis in the laboratory led to a redesign of parts of the injection and sampling equipment and modifications to the evaluation techniques. The diameter of the injection and sampling probes were increased to avoid recurrence of mechanical failure due to vibration [p. 10, F.R.59]. Originally the injection rate was metered by use of a calibrated orifice plate and a 4 ft. manometer. In the present tests the gear meter was used to give direct readings of the amount injected over a period of approximately 3½ min., a check on the constancy being obtained by a mains-operated counter driven from a semi-conductor photocell unit which was triggered 66 times during each revolution of the main drive in the gear meter.

† *See also* Water Power, *loc. cit.*

The time signal for this, giving a 10 second count, was provided by the same battery-operated transistor crystal frequency standard used at the salt-velocity station. As for the initial tests a standby injection pump was incorporated in the apparatus.

The salt used was again sodium dichromate ($Na_2Cr_2O_7 . 2H_2O$), the strength being varied for the two flow rates from 100 to 150 g/l. The dilution ratio was determined by volumetric analysis, using both indicator and titrator methods described in F.R.59 and for the final test by colorimetric means, the strength of the injected solution being reduced to one-tenth, i.e. 10 g/l, for this test.

The significant departure in analysis technique was that a 1/1,000 standard dilution of the concentrated solution was made up at the time of the test itself using water from the pipeline. Clear line water samples were also withdrawn at the sampling station for the further dilution of this standard in the chemical analysis to ensure freedom from extraneous effects between samples and standards.

Test Procedure and Evaluation of Measurements

Although some of the equipment was again experimental and thus on test, planning of the programme was for field tests proper, allotting one day each to the measurements at the two flow rates chosen, irrespective of the performance of the apparatus. Failure at one station was not to affect the schedule of testing at the others.

Prior to a test run, each station phoned a readiness report to the control room, from which the starting signal was given. From then on the current-meter station was in continuous operation, measurements at the pitot-tube station were taken as frequently as manometer settling time permitted, while injecting, recording and sampling at the other two stations followed a predetermined schedule to ensure that salt-velocity and salt-dilution tests did not interfere with each other.

CURRENT-METER STATIONS

All test results from both stations were simultaneously filmed, the timer unit operating for the greater part on "automatic repeat." This included the two transistorised counters of the modified Amsler current meter which recorded on a combination of these and the standard electromagnetic counters. Due to an electric fault which developed in the insulation of the photocell circuit under the high line pressure of approximately 390 lb. per sq. in., the unit failed to operate satisfactorily. An attempt to determine the effect of possible fluctuations in the line, the objective in using the Amsler current meter, was made at the end of the tests by reducing the standard recording time of 200 seconds in steps to a shortest recording interval of 20 seconds.

By means of the log. linear method of integration,[9] taking account of results from the outer and inner ring of meters only at station 1, Fig. 3, one operator using a hand calculating machine could obtain an answer within fifteen minutes under field conditions. This reduced to approximately five minutes by use of the "mean value characteristic" method.[12] With electric calculating machines, the eight-point log. linear result is available in about five minutes, the "mean value characteristic" result in less than two minutes.

Field results from the second current-meter station, again using log. linear methods of computation, were produced within five minutes.

Although the numerical log-linear methods of integration have since more directly been proved superior to the graphical ones,[10, 11] in compliance with power test code specifications, ten randomly selected tests have been graphically evaluated in two different ways. Of these, seven differed by less than 0·4% from the log. linear results, while the variation in the remaining three was less than 0·7%, the arithmetic mean being less than 0·5%.

PITOT-TUBE STATION

The measurements at this station had been planned as an investigation into several different aspects of the metering of flow rates by pressure probes. Operating under the unusually high pressure of 300 lb. per sq. in., a severe test for the equipment used, the station had been suitably arranged to make a direct comparison possible between results obtained here and farther downstream at the current-meter stations, one station thus providing a check on the performance of the other.

A further point of interest was the comparison of results obtained on one diameter only with measurements carried out with the two probes in consecutive traverses on two diameters perpendicular to each other.

Lastly, readings were taken at the four 0·112*D* positions on the two diameters, and the results analysed both individually and by computing the mean of those measured during the span of a full pitot traverse.

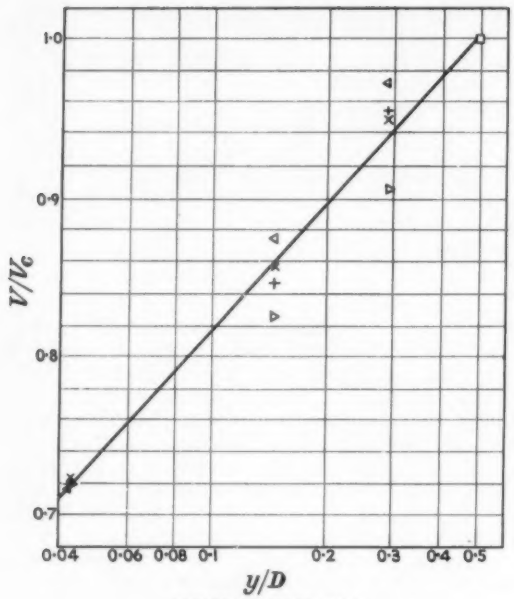
The time required for a complete set of readings was approximately 75 minutes, and consisted of eight-point traverses with probes I and II, which in addition included readings at the 0·112*D* positions. Manometer fluctuations in the probe pressure readings of the order of ± 10 mm. were damped out by use of special throttling valves. Evaluation, carried out at East Kilbride, was by both the eight-point log. linear method[9] and by graphical analysis, whereby in five of the six traverse tests the results obtained by the former differed by less than 0·5% from the latter; in one case only was there a discrepancy of 0·87%. Computation of the results from two traverses took one operator an hour to complete.

At site, only the readings from the 0·112*D* positions were evaluated.

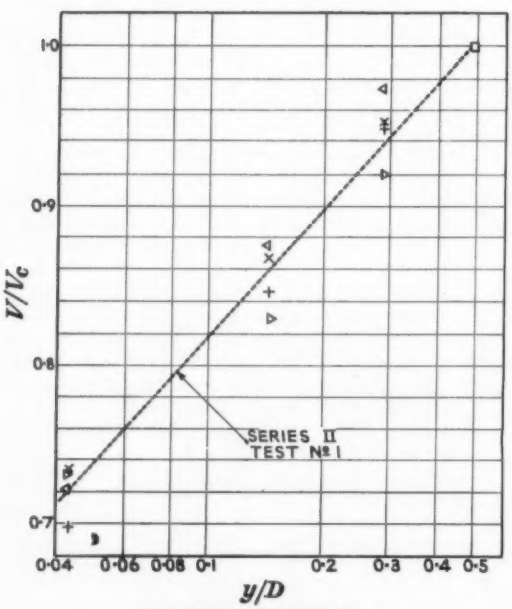
SALT-VELOCITY STATION

The two bridges and their oscillator-detector units, each connected to one electrode, were equipped for balancing out the capacitance and inductance of electrodes and connecting leads, as well as the initial resistance of the water in the pipe. The amplified bridge output was applied to one beam of the double-beam oscilloscope and simultaneously to one of the pens of the high-speed pen recorder. The other beam and pen carried the timing signal from the crystal frequency standard.

The sequence of operations started with the priming of the injection valve and loading of the cartridge in the breech, after which the "ready-to-fire" signal was passed to the recording station. The bridges were then checked for satisfactory balance, after which instruction was given to fire the injection valve. Pre-



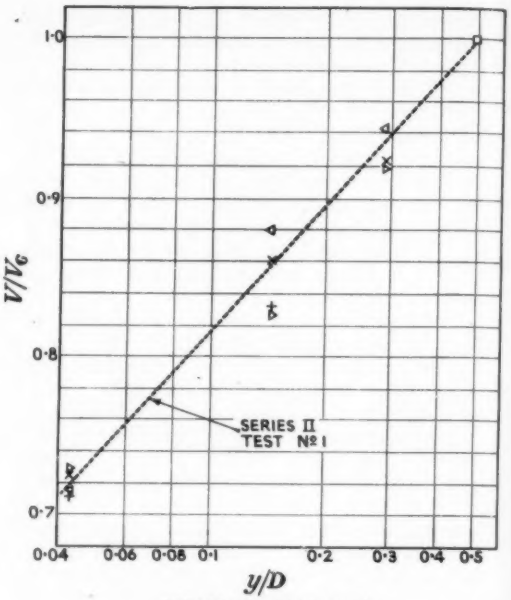
SERIES II TEST Nº 1



SERIES III TEST Nº1

liminary trials were run to establish amplifier gain settings, balance, etc., and the times between firing and detection at the first and second electrodes. The oscillographs were thus only operated for a period sufficient to obtain records. Meters showing amplifier outputs enabled the satisfactory nature of a run to be assessed. At full flow rate, the whole sequence of operation was accomplished in an average time of one minute, and a rate of ten injections in ten minutes was sustained.

Of each test, 35 mm. records were taken and the readings of the automatic timer recorded. Final



SERIES IV TEST Nº 22

RADIUS 1	: ▷,	METERS	1, 5, 9
RADIUS 2	: ×,	METERS	2, 6, 10
RADIUS 3	: ◁,	METERS	3, 7, 11
RADIUS 4	: +,	METERS	4, 8, 12
CENTRE	: □,	METER	13

Fig. 5. Test results plotted against the logarithm of the dimensionless distance from the wall

evaluation was carried out at East Kilbride in this case for convenience, though the tests in June had shown it was perfectly feasible to evaluate results in the field.

Salt-Dilution Station

As in the initial tests, the concentrated solution of sodium dichromate was recirculated by the appropriate pump prior to injection to ensure steady conditions before and during a test. Both pumps were used, the strength of the solution being varied to obtain a final concentration in the dilute samples of about 10 p.p.m. dichromate for the tests analysed volumetrically and about 1 p.p.m. for the colorimetric test.

When the signal was received to commence a test run, the 600 ml. bottles were filled with clear water at the sampling station. After a sample of the concentrated solution had been drawn off, the actual test could be started, the chemical being injected into the line normally for four minutes. The rate of injection was measured by the calibrated gear meter and immediately after the test a further sample of the concentrated solution was taken, and from this a standard 1/1,000 dilution was made up using clear water from the pipeline.

The normal test duration of ten minutes was therefore divided between obtaining clear samples, the injection time of the salt and the sampling sequence which was delayed by approximately two minutes, the time taken by the salt to reach the sampling point. For each test at least ten samples of the diluted chemical were drawn off into the sample bottles, 50

ml. bottles being used for the colorimetric tests. Two operators were needed when samples were taken from both probes at the same time.

In four of the tests the salt-dilution ratio was determined by volumetric analysis using an indicator, in another four by using the automatic titrator, and in one test by a colorimetric method. In the indicator and titrator methods 500 ml. of the dilute samples are titrated against a ferrous ammonium sulphate solution. Standard dilutions are similarly titrated so that the unknown ratio can be found. In the analysis by colour absorption, where a difference of one per cent. in the strength of the dilute samples calls for a detection sensitivity of one part in one hundred million of dichromate, only a simple instrument was available. Despite the disadvantages of zero drift and low reading accuracy in this instrument, careful techniques enabled results comparable with those from the volumetric method to be obtained. The concentration of the salt was measured by the absorption of light at a wavelength of 561 millimicrons, using diphenylcarbizide to develop the colour intensity which is proportional to the amount of salt present. Details of all three methods may be found in reference 27.

Six of the tests were analysed in the chemical laboratory at the Kinlochleven works, where space had been made available. The remainder, including the colorimetric test, were analysed at East Kilbride.

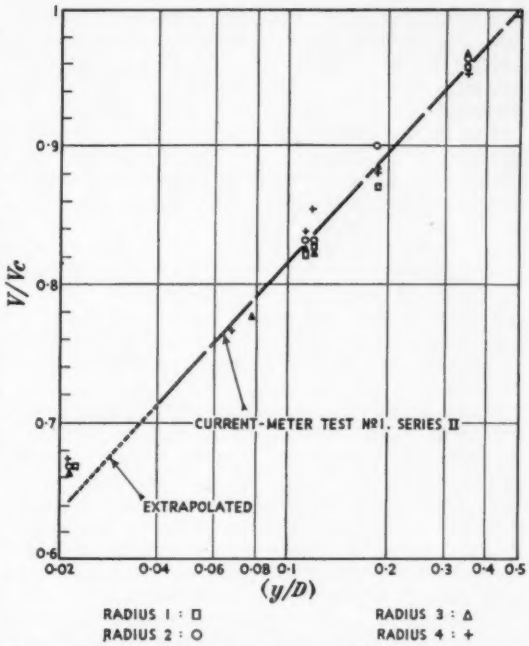


Fig. 6. Logarithmic velocity distribution at the pitot-tube station

Discussion of Results

For clarity of presentation, the four methods will first be considered separately, after which they will be compared.

CURRENT METERS

Some difficulty was experienced on the first morning of the tests at station 1 due to the high conductivity of the water, which affected the contacts of the small meters and necessitated minor adjustments to the counter relay circuits. By the afternoon the station was in full, and from then on, continuous operation until the end of the tests, with all thirteen meters recording. Performance of the large Ott meters, with contact chambers more effectively protected against the penetration of high pressure water, was entirely satisfactory.

Since the results from station 1 were again to be used as reference, the current meters with a standard deviation σ of the order of $\pm 0{\cdot}2\%$ being the most consistent of all the methods on test, records obtained on the first morning have been treated as those of trial runs. Results obtained on the same day during tests series II revealed an almost constant difference between the simultaneous results from the two stations, the mean of which was $+0{\cdot}71\%$; this value was subsequently used to *compute* from the results of the second station during the morning run the records of station 1. A glance at Fig. 4 reveals that this procedure seems indeed justified. The deviations of the salt-velocity and the salt-dilution methods, in this context the only meaningful ones, are of the same order of magnitude whether computed or measured current-meter values formed the basis of comparison.

It has been shown in reference 14 that the overall standard deviation and hence the random error of a current-meter calibration was $\pm 0{\cdot}27\%$, on the strength of the simultaneous calibration of thirteen meters. This therefore constitutes the possible systematic error in the field measurements. The standard deviation in the field tests was of the order of $\pm 0{\cdot}25\%$ or less, so that systematic and random errors were of the same order of magnitude. Test duration for both stations, since all results were recorded on the same counter panel, was 200 seconds, except for tests 17 to 21 of test series IV; for these the timing intervals were 20, 40, 50, 70 and 100 seconds respectively, the last test of the measurements, test No. 22, being again recorded for the standard 200 seconds interval. The standard deviation of the grouping of results containing these measurements was $\sigma = \pm 0{\cdot}23\%$. The variation in the results obtained by short recording intervals is found to be quite comparable to that found for the 200 sec. runs. It should be noted here that these findings establish the steadiness of the flow and rule out the possibility of rapid fluctuations being superimposed over the mean velocity, which was originally considered as a possible explanation of some of the results obtained during the initial tests, see p.10, F.R.59; reference to this will be made later.

In view of the relative nature of the comparison between the four methods, it is essential to ascertain, as far as this can be done, the consistency of the current-meter readings, estimates of accuracy having been given already. This has been done by plotting results of the very first test, the last, and of one test in between against the logarithm of the dimensionless distance from the wall, as seen in Fig. 5. The slope of the log. linear distribution of Fig. 15, the first test recorded at station 1, has been replotted into the two other graphs prior to plotting the results. The resulting agreement is sufficiently good to suggest that no significant variation occurred in the current-meter readings at station 1 over the whole duration of the test; this is particularly true if account is taken of the

fact that by making all readings dimensionless with that of the meter on the centreline, results may be affected by the possible variations in the readings of this meter stated to be approximately $\pm 0{\cdot}27\%$. Further evidence of the consistency of the current-meter results from station 1 is given in Fig. 4, series II, III and IV, in the band width of the scatter which results from a comparison of individual tests with the mean flow rate of the series. With the exception of a single one, all results were within $\pm 0{\cdot}25\%$ of the mean. Further proof of the consistency and accuracy of the current-meter results will be presented in the discussion of the pitot-tube findings.

Flow rates obtained by the method of the "mean value characteristic"[12] gave results throughout which differed by only 0·05% or less from the log. linear results.

It has previously been stated that station 2, with four large meters mounted in the region of a velocity gradient, was considered as an experiment only. Results obtained were consistent and at the lower flow rates differed by less than 1% from those of station 1, Fig. 4, series II. At the higher rate of flow, however, this deviation increased to a maximum of 2%, Fig. 4, series III and IV. For this there is no ready explanation. The possibility of a slowing down of the reference meters at station 1, resulting in a change of approximately 1·3%, may be ruled out on the strength of the evidence in Fig. 5. The drift in the individual meter readings cannot possibly account for a variation of this magnitude, and the excellent agreement between the slope of the first current-meter tests with the results of the last pitot traverses, Fig. 6, may be taken as final confirmation of the correctness of the results obtained from station 1.

Pitot Tubes

A part objective of these tests was the comparison of individual results at the $0{\cdot}112D$ positions, of their mean over the time taken for a traverse and of a traverse on a single diameter both with the results of traverses on two diameters and the current-meter values from station 1. With reference to Fig. 4, series II, III and IV, the individual readings differed in the worst case by $-1{\cdot}9\%$, the majority by less than $-1{\cdot}5\%$. Their mean deviated by less than $-1{\cdot}2\%$.

Individual traverses with probe No. 1, tests 1, 2 and 3, differed by $+0{\cdot}46$, $-0{\cdot}16$ and $-0{\cdot}4\%$ respectively from the current-meter results. Results from traverses on two diameters, tests 4, 5 and 6, agreed to within $-1{\cdot}04$, $-0{\cdot}48$ and $-0{\cdot}23\%$ respectively with the current meters. In computing the latter, the wall-nearest readings of probe No. 2 were corrected by replacing them with the corresponding values of probe No. 1. This was prompted by results which differed substantially from the log. linear values at this position of measurement; when used without correction, agreement to within 0·1% was obtained by reference to the current-meter results from station 1. However, during installation of the probes it had been noted that the flame-cut insertion hole for probe No. 2 was heavily burred, and the readings hence obviously in error. The correction, although weighting the method with a larger deviation, was obviously called for.

Fig. 6 shows the close agreement between the pitot-tube and current-meter measurements in a comparison of the dimensionless velocity distribution at two different rates of flow as represented by the first current-meter test and the last pitot-tube test. The standard deviation of the pitot-tube method on the strength of the limited number of tests was $\sigma \simeq \pm 0{\cdot}3\%$.

Salt Velocity

The deviations of the means of up to eleven individual shots differed to an extent which depended both on the rate of flow and the method of evaluation used. Thus the deviation amounted to as much as -3% at the low flow rates for the "mean amplitude" method, which reduced to -2% or less by use of the "centre of gravity" technique of evaluation, Fig. 4, series I and II. At the higher rates of flow, the differences due to the mode of evaluation were less pronounced and the majority of the results was within $\pm 1\%$.

In Fig. 24 (F.R.59) a large-scale plot of the individual shots was presented which revealed a distribution of the flow rates, determined from the single shots, which did not seem to be entirely randomly distributed around the mean. This led to the men-

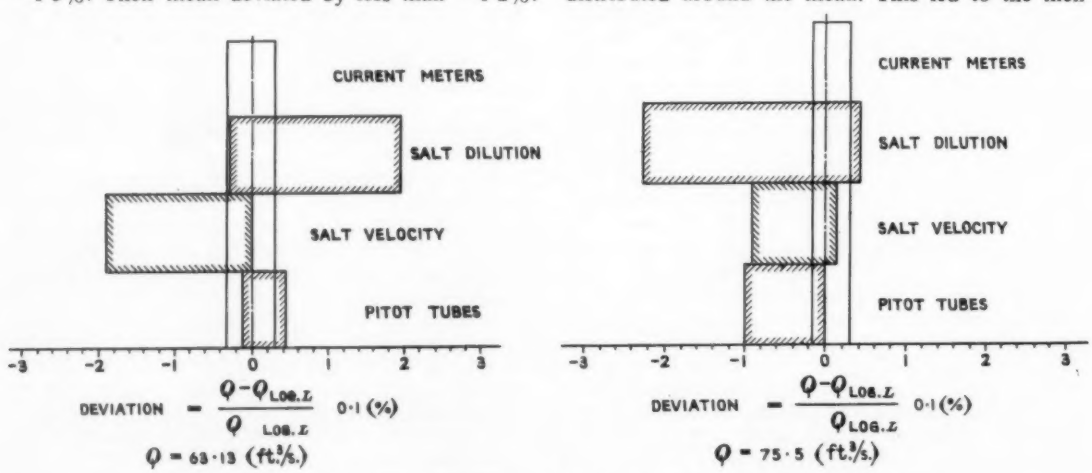


Fig. 7. Summary of results presented in the form of maximum deviations

tioned modification of the Amsler current meter, in the attempt to check on the possible, if unlikely explanation of rapid fluctuations being superimposed over the mean velocity. The failure of the meter, still very much in the experimental stage, made this impossible. It was, however, attempted to supply the desired information by reduction of the current-meter recording interval to as little as 20 seconds, the results being equivalent to those obtained for a duration of 200 seconds. Yet the distribution of the results from individual shots was again quite similar to those shown in Fig. 24 (F.R.59), and must therefore be accepted as inherent to the method. The standard deviation of the results obtained by the "centre of gravity" method was of the order of $\sigma = \pm 1{\cdot}6\%$ and slightly more for the "mean amplitude" technique.

Salt Dilution

The standard deviation of the individual tests, a little over $\pm 1\%$, was of the same order of magnitude as that obtained in the preliminary tests. A substantial improvement in reliability and accuracy was evidenced, however, in the readings, eight of the nine tests being within a band of $\pm 2\%$ from the current-meter results, while the ninth gave a deviation of $-2{\cdot}3\%$. No significance could be attached to the swing from generally positive deviations at lower flow rates to negative values at the upper rates. Samples from both probes were taken in test No. 3, series I, and gave almost identical dilution ratios; in series III both probes were operated in all tests, the variations of the mean values all being within $\pm 1\%$. Since there was no bias in favour of one of the sampling positions giving results closer to the current-meter measurements, it was considered that mixing was adequate, the variations being caused by analytical random fluctuations. The colorimeter test gave promise for a considerable reduction in the size of sampling and injection equipment required, although an improved absorption instrument is needed to exploit this technique. Further improvement in the scatter band width is aimed at, but most of the shortcomings found in the initial tests have been overcome.

Comparison of the Four Methods

The majority of the results at both rates of flow is within $\pm 2\%$ from the current-meter results, with the exception of the salt-velocity values obtained for the low flow rates by the "mean amplitude" method of evaluation. Agreement at the increased rate of flow is within $\pm 1\%$. There is no evidence of any systematic bias in the salt-dilution results obtained by different methods of analysis, which for the greater part differ by less than $\pm 2\%$ from the reference. The pitot-tube findings from individual as well as traverses on two diameters agree to within $0{\cdot}5\%$ with the current meters, whereas individual readings at the $0{\cdot}112D$ positions vary by as much as $-1{\cdot}5\%$.

In Fig. 7 the summary results are presented as maximum deviations, and it is seen that on this basis current meters and pitot tubes appear the most consistent and accurate, followed next by the salt-velocity and last by the salt-dilution method. This sequence is not significantly changed by consultation of Table I, where the four methods have been compared on the basis of equipment required and efforts involved in installation and evaluation. The longer installation time required at the pitot-tube station and a test duration of 75 minutes must be weighed against the greater time requirements for the evaluation of the salt-velocity results. Values in brackets are the times recorded during the first Kinlochleven tests, the considerable reductions in time realised in the final measurements being qualified in column 3 of the table. It should be noted that the figures given for the current-meter method do not take account of man-hours spent on calibration, which are quite considerable but difficult to assess.

Conclusions

The current-meter method gave the most consistent results and required less man-hours for installation of one station and for evaluation than any of the other methods. The standard deviations of the results computed by log. linear methods from the readings of eight meters at station 1 were again the smallest of all results recorded, whereby the deviation from the flow rates determined graphically by use of all thirteen meters was less than $0{\cdot}5\%$. Time requirements for evaluation have been further reduced through the development of novel, accurate computing methods.

Results obtained from the experimental second current-meter station, equipped with four standard-sized meters, were within 1% of the reference at the lower flow rates, but differed unaccountably by as much as 2% at the higher ones.

Log. linear plots and comparison with the pitot-tube results revealed the absence of any significant drift in the current-meter results from station 1.

The meters functioned satisfactorily under a line pressure of approximately 370 lb. per sq. in. and 390 lb. per sq. in. respectively; they were submerged for more than 72 hours.

Reduction of the recording interval in stages from the standard duration of 200 seconds to 20 seconds had no significant results.

The pitot-tube station operated satisfactorily, with traverse results from one and two diameters within -1% of the reference. The mean of readings taken at the four $0{\cdot}112D$ positions (equivalent to those of the four current meters at station 2) during one test differed by less than $-1{\cdot}2\%$, while single readings deviated for the most part by less than $-1{\cdot}5\%$. As with the current meters, log. linear methods of evaluation were used, results varying again from those obtained by graphical analysis by less than $0{\cdot}6\%$. In consistency and man-hour requirements for evaluation it rates next after the current-meter method, and is on a par with the salt-velocity and salt-dilution methods for installation effort. It is, however, the most unfavourable of all the methods with respect to test duration, which for a complete set of results from two diameters extended over 75 minutes.

The salt-velocity apparatus performed satisfactorily; mean results at the low flow rates agreed to within -3% with the current-meter reference if the "mean amplitude" method was used for analysis, and to within -2% for values obtained by the "centre of gravity" technique. This discrepancy became less obvious at the higher flow rates where most results were within $\pm 1\%$ of the current-meter ones.

The automatic timer is a most promising development and may prove a major advance in this method of metering flow.

The salt-dilution equipment, partly redesigned since the initial tests, was satisfactory in performance. The

marked improvement on the results from the preliminary tests—the scatter band was now within ±2% of the current meter readings with the exception of one test at −2·3%—was attributed mainly to the use of line water at all stages of the analysis for comparing standard known dilutions with the diluted samples. In man-hour requirements for evaluation the method is little different from the salt-velocity technique while it has an advantage over all other methods that no access to the inside of the pipe is required either for mounting equipment or for measuring the dimensions of the pipe.

On balance, it is evident that none of the methods compared can be stated to be absolutely superior to the others. The choice of method will in each case be decided by the requirements of the test to be carried out, in the light of which the features of the different techniques must be reassessed.

Acknowledgment

As Chief of Tests, the writer wishes to express on behalf of the National Engineering Laboratory's party once more the appreciation felt by all for the splendid assistance given by the staff of the British Aluminium Company. Thanks are in particular due to Mr. Weston, Manager of the Kinlochleven Works, and Mr. Hinshelwood, whose active interest contributed largely to the success of the tests.

He wishes further to acknowledge his indebtedness to Mr. W. H. P. Leslie, head of the Electronics Section, who was in charge of all electronic and communication equipment, to Dr. E. A. Spencer and Mr. L. Young, who headed the salt-dilution and salt-velocity groups respectively, for their close collaboration, and to all others who took part in these tests in a spirit of true team effort. Papers by Dr. Spencer and Mr. Young[23, 27] have been consulted in drafting the relevant sections on salt-dilution and salt-velocity measurements, and their assistance is gratefully acknowledged.

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TABLE I.—COMPARISON OF METHODS ON BASIS OF MAN-HOUR REQUIREMENTS FOR INSTALLATION AND EVALUATION

Method	Installation (man-hours)	Evaluation (man-hours)	Comments
Current meters ... (Stations 1 and 2)	13; (20·5)	Log. linear 8 results, el. comp. mach.: 0·10.	Complete mounting sequence, measurement of pipe.
		Log. linear 8 results, field: 0·25	Detailed preparations reduce time requirements by approximately 10 hours.
		Log. linear 4 results, *field: 0·10	
		2 graph. integr. 13 meters, planim.: 0·75	
Pitot tubes ...	16; (28)	Log. linear 16 results, el. comp. mach.: 1·0	Mounting of pitot tubes and associated equipment, measurement of pipe. Detailed preparations cut time requirements by approximately 7 hours.
Salt velocity ...	5; (28)	Including developing and drying of film record of eighteen tests: 3	Valve mounted from outside, pipe not measured. Time requirements reduced by approximately 4 hours.
Salt dilution ...	15; (23)	Indicator method: 3 Automatic titrator: 3 Colorimeter method: 3	Complete mounting sequence. Modifications to equipment result in reduction of time requirements by approximately 8 hours.
Power supply for methods 3 and 4 (Laying of cable)	13·5		

* Identical to man-hours required by method of "mean-value characteristic" employing 8 points

NOTE: Figures in brackets refer to preliminary tests.

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Aerial Survey and Electronic Computing

A successful attempt has been made to combine electronic computing with aerial survey to speed up the conversion of the data obtained into useful results. The possibilities and applications of aerial survey for hydro-electric planning have been fully discussed in WATER POWER, January 1957, p. 20; and in a recent visit to Hunting Surveys Limited and Elliott Automation Limited, both of Elstree Way, Boreham Wood, Herts., we were able to observe a demonstration where an aerosurvey was analysed with the aid of an electronic computer. As often happens in any hydro-electric project, it is the nature of the terrain which determines the approximate dam site, and sometimes that site is in an area in which roads and transport facilities are either poor or non-existent. Aerial survey and photogrammetric methods can give the terrain cross-sections at intervals, and reservoirs are superimposed on a grid system. The accuracy that has been obtained is of the order of 0·3% for volumes and 0·77% for areas. The computer can be effectively utilised for the road-construction programme. It is able to calculate the cut-and-fill volumes, compaction factors, corrected volumes, areas and mass haul, at the rate of 3 miles of roadway per hour. This figure has since been improved. For a complete strip survey, Hunting Surveys Limited estimate the cost to vary between £300–£400 per mile, depending on the terrain and country. This may not be competitive with the orthodox methods of surveying but it is certainly quicker—and, used in conjunction with electronic computers, the engineer is able to devote his time and judgment to the design problems rather than be faced with the drudgery and desk work of repetitive calculations.

Recent Gilbert Gilkes & Gordon Orders

Gilbert Gilkes & Gordon Limited, of Kendal, have recently received an order from the City of Revelstoke, British Columbia, for a Turgo impulse water turbine to develop 5,800 h.p. on a head of 770 ft. The consultants for the scheme are Sir William Halcrow & Partners (B.C.) Limited, and the order was placed through Electric Power Equipment Limited, Vancouver.

Other orders for Turgo impulse wheels placed during the past year include a 1,000 h.p. unit for Shillong, India, and a 725 h.p. turbine for the Municipality of Ceres, Union of South Africa. Smaller powered turbines of the same design include two machines for Abercorn, Northern Rhodesia, and additional units for Goroka, New Guinea, and Sasumua Waterworks, Kenya.

An interesting Gilkes installation recently commissioned is the 3,440 h.p. Francis turbine at the North of Scotland Hydro-Electric Board's Cuaich power station. This drives a 2,500 kW induction generator and the unit is entirely automatic, being controlled by the variation in the level of Loch Cuaich. Gilkes overseas erection staff have also just installed and commissioned a 1,200 h.p. asynchronous unit at Pitman's Pond, Newfoundland, and a second 240 h.p. Francis turbine at Mbeya for the Tanganyika Electric Supply Co. Ltd.

Electrical Development in Water Power Engineering

A forecast is made of likely trends during the next fifty years in the design of the electrical equipment used in hydro-electric systems

THE sixty years of this century have seen remarkable changes in technique and scale of achievement in all branches of water-power engineering. It is the purpose of this article to discuss the electrical progress that has been made, and to touch on possible future trends.

Generators

By 1900, the basic principles of electrical generation were firmly established on the same lines as those now in use, that is, generation by salient-pole three-phase alternators, usually wound for a voltage of from 3,000 to 10,000 V. Direct distribution to the network was the most frequent system, but interconnection of power stations was beginning, on an experimental basis, and higher voltages, up to 66,000 V or even higher, were beginning to make their appearance. Now—sixty years later—the essential elements of the design of water-turbine alternators have remained unchanged. The size of individual units, of course, has greatly increased, but the introduction of fabricated construction has enabled relatively small, easily transportable sections to be taken to site and assembled as satisfactorily as a factory-made unit.

It is often said that whereas steam-turbine units may go up in size (of single-shaft sets) to 500 MW or even larger, water-turbine generators are not likely to be built above 300 MW owing to the inherent limitations of any slow-speed machine. If this is true, we may well have reached the final stage in turbine design.

In the field of thermal power there is always the possibility that some electro-chemical discovery (such as the fuel cell, or a magneto-hydrodynamic device)

Fig. 1. One of the three 150 MVA ASEA generators in Stornorrfors station, Sweden

Fig. 2. The first 100 MW generator for Kariba on test in the AEI works

might revolutionise the whole process, and render the steam turbine obsolescent. But so far, no suggestion has been made that the energy in falling water could be commercially captured in any other way than by the use of turbines and electromagnetic generators. If it is then considered that the water-turbine generator is here to stay at least for the next fifty years, it is interesting to speculate what detail changes in design may be expected.

Greater outputs will undoubtedly be obtained from given frame sizes. The designers of steam-turbine-driven alternators have been rapidly increasing the hydrogen pressures inside their stator casings, to carry away more heat and reduce windage. They have also resorted to liquid and gas cooling, associated with hollow conductors, on both stator and rotor windings. So far these measures for increasing heat transfer have only penetrated the hydro-electric field to a minor degree. The use of improved forms of insulation for stator conductors, however, has been almost as widely applied in water-power alternators as it has in steam-driven designs.

Metallurgists are constantly improving the steels available to the generator designer, both those used for the main construction and the special magnetic steels used for the active parts.

Progress towards lighter, smaller and cheaper generators may come much more slowly in the hydro-electric field than it has in the higher-speed versions, but significant advances may well be recorded in fifty years' time, even if the general principle of the machines remains the same.

The use of asynchronous generators for relatively small units may be considerably extended. Rising costs of skilled labour in practically every part of the world are leading to the progressive elimination of operating staff in all but the largest stations. The induction generator, automatically brought on load by remote control, or even by time switch or reservoir level initiation, is perhaps the simplest and most reliable device now available for power generation.

Computer Control

The use of electronic governors and voltage regulators is increasing; and with the steady extension in the size and range of interconnected power systems, involving hydro, thermal and nuclear plant, all with differing characteristics, the question of system stability is likely to become of paramount importance. Thus, in the next ten years, computers may be applied to the entire control of a hydro-electric station. Such devices will have sections taking complete charge of the generators, and giving a closeness of control for both frequency and voltage considerably in excess of anything at present achieved. Yet relaxation of frequency control, on a predetermined and automatically applied basis, may be provided by the computer when system conditions make it desirable.

The computer-controlled stations of the future are likely to make the most advantageous use of hydro power by assessing total system demand at any instant in conjunction with abundant data continuously fed into the computer memory devices, such as incremental costs at adjacent fuel or nuclear-powered stations, cumulative rainfall data and available stream flow, transmission-system loading, and forecasts of system demands over the next hourly or daily periods. From all these data, assessments may be made of the number of generating units to be brought on load and the duration of running for each unit. Automatic starting, regulating and stopping gear will then take control, running units as needed, and at the same time monitoring every vital quantity, such as oil pressure, winding temperature, rotor earth leakage, and so on.

Transformers

Main transformers have undergone considerable changes in the last fifty years, arising from the increasing employment of cold-rolled grain-oriented steel for the laminations. This has reduced losses, increased efficiency, and permitted the use of very much smaller dimensions for a given power-transfer capacity. This new steel first encouraged a trend towards larger and larger three-phase units, and then, as transport limitations supervened, to types of construction (as developed especially in the U.S.S.R.) whereby very large single-phase units can be assembled on site.

At present the auto-transformer is finding increasing favour in large power systems. The much-debated question as to the true value of factory impulse tests in evaluating the performance of large power transformers under service conditions has been dying down in regard to three-phase units. Here the highly satisfactory behaviour of such units under surge and lightning stresses, in networks of every kind, has shown that relatively few further problems remain. The debate now shows signs of rekindling in regard to auto-transformers, and during the next two or three years the reactions of auto-transformers to impulse tests, to transients encountered in system operation, and to short-circuit stresses may be closely studied. After this period the auto-transformer, in both single-phase and three-phase forms, is likely to become the accepted design for all large power transformers. Even at present there are clear indications that its behaviour under service conditions is at least as good as that of two-winding units.

Circuit Breakers

The generators of the future are no more likely to have circuit breakers interposed between them and their step-up-transformers than is the case at present. Switching, on the high-voltage side, is more and more tending to be carried out by air-blast circuit breakers. Even that stronghold of the bulk-oil type, the U.S.A., is surrendering to the advantages offered by air-blast breakers, mostly (so far) manufactured either in Europe or from European designs. Low-oil-content breakers are competing strongly in some fields with air-blast designs, particularly in view of the current trend towards making these breakers in units which

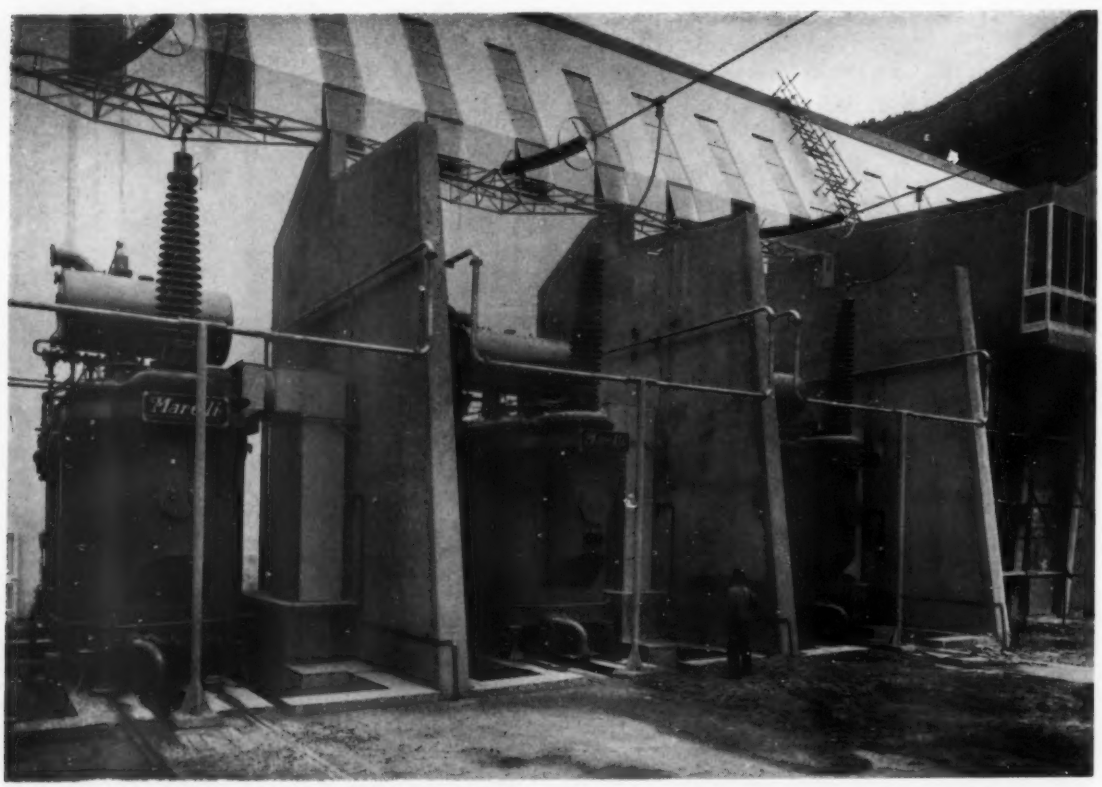


Fig. 3. A 110 MVA 13·8/240 kV bank of Marelli transformers at Cimego station, Italy

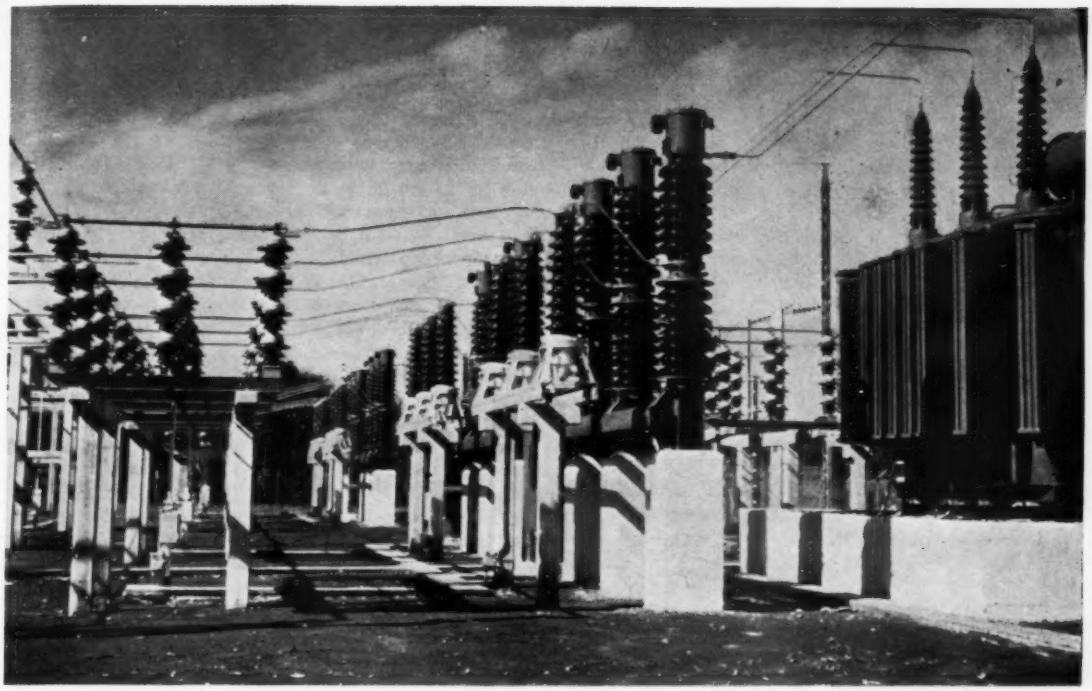


Fig. 4. Part of the 132 kV switchyard at the Innisfail substation of the Tully Falls scheme, Queensland, incorporating Reyrolle small-oil-volume switchgear

can be built up in series to arrive at any desired voltage level.

Present tendencies in circuit-breaker design include the use of sulphur hexafluoride as the insulating and arc-quenching medium, and the increasing interest in vacuum-type breakers. This latter development, in which the British and Allied Industries Electrical Research Association is taking the lead, is still far from reaching the stage of commercial application, but the outlook is extremely promising. It is in the circuit-breaker field that the most interesting advances may be expected in the next fifty years. Generators for waterwheel drive, transformers and overhead lines are not likely to change in essence, but in 1960 it cannot be said that finality has been reached in circuit-breaker design. Every two years, the CIGRE Conference (The International Conference on Large Electric Systems) provides news of fresh designs. French manufacturers have pioneered interesting lightweight suspended breakers, of the air-blast type, and Swiss designers have produced extremely slender, tall columns of insulators on top of which are perched series-connected air-blast units with their associated shunt resistors.

New principles of circuit breaking may be discovered, embodying the extinction of the arc at the first current zero. An arc is maintained, if it *is* maintained, by the presence of an ionised substance between the electrodes. The rapid progress now being made in the semiconductor field, in which the whole structure of materials is altered, may mean that non-ionisable materials can be produced. If a switch so equipped were to be operated in a vacuum, the perfect circuit-breaking principle would probably emerge, subject only to such detail developments as the transformer has undergone in the last fifty years.

As power interconnection increases, the short-circuit currents encountered by prospective switchgear installations will become very heavy, and it is not at all certain that the extrapolation of the present-day switchgear designs will form an adequate approach to future problems. Thus the need to embark on an even greater programme of fundamental research in the circuit-breaking field is apparent.

Protective Equipment

Protective devices have changed greatly in the last fifty years. Simple relays for overcurrent and earth-leakage detection, incapable of discrimination, gave way to complex systems in which the tripping times were related to the distance of the fault current from the circuit breaker affected, and where means were provided for co-ordinating the protective gear at the two ends of the protected section. Most forms of protection nowadays operate on a balance principle, whereby the characteristics of the input current to a unit of equipment, such as a transformer, is compared in one way or another with the characteristics of the outgoing current.

Where overhead lines are concerned, the necessary linkage between the ends is provided by high-frequency carrier-current systems working on the line conductors themselves. The very great increase in the usage of this type of communication channel has been a striking feature of the last decade. It is linked also with the remote control of substations through the same means. Much work has been done on the exploration of the characteristics of high-voltage power

lines when considered as high-frequency channels. The number of frequency bands in use is continually increasing. It is possible nowadays to predict with reasonable certainty the attenuation that the high-frequency channels will encounter, not only in sound conditions but also in cases of bad weather, fault, or other abnormal circumstances.

In the future, the transmission lines may be used more and more extensively for system control. The protective gear with which the carrier channels—themselves transistorised—are associated is tending to become increasingly made up of semiconductor devices, eliminating the problems caused by faulty operation of electro-mechanical equipment such as relays. There are also the positive advantages that simpler and yet more sensitive protective devices may be used. Semiconductor rectifiers enable d.c. relays and d.c. circuits to be employed in stages where much more complicated a.c. devices had to be used in the past.

The use of semiconductor devices may bring another advantage. With their aid, it is possible to build on to the live overhead line itself, or on to any component, such as a busbar, a device which is entirely self-contained and which can give out micro-wave radio signals to a nearby grounded receiver to indicate current and voltage conditions in the main conductor. These transmitters can be made of miniature transistor-like modules, drawing their small requirement of low-voltage power from a small storage cell, fed with rectified current from the drop across an almost insignificant resistance in the main high-voltage circuit.

The protective gear of the future is likely to take the form of very small and compact semiconductor units, the characteristics of which will be automatically varied by computer elements according to the network conditions.

Power Transmission

Turning now to the transmission of the power generated by future hydro-electric stations, the most notable feature of the last fifty years has been the increasingly rapid rate of rise of voltage level. As more and more hydro schemes near centres of industry became fully harnessed, transmission voltages rapidly soared from the 33 kV level to 100 kV, and onwards very soon to 220 kV. Then in 1956 the Swedish lines became the first in the world to work at 380 kV, followed fairly rapidly by the Russian 400 kV lines commissioned in the last two years. In other countries the former 220 kV networks are quickly being converted to 380 kV working; and new schemes, such as the Kariba and Snowy Mountains projects started off at the 330 kV level. Now, in 1960, the Russian engineers have already started work on converting their 400 kV lines to 500 kV. In America, where 345–360 kV has been the highest transmission

Fig. 5. The remote-control desk at Owen Falls, equipped by Standard Telephones and Cables Limited

voltage so far, a 650 kV experimental project is under way.

Allied to this increase in voltage has been a determined attack on what has been called the most troublesome problem of all high-voltage transmission development—interference with radio and television. There has been almost universal acceptance of the bundle-conductor principle, whereby the electrostatic field is "spread out" and so diminished in intensity at any one point. Much progress has been made in the design of the equipment—insulators, arc-control devices and anchoring arrangements—associated with the high-voltage conductors, so that corona losses have been sensibly diminished and radio interference limited. In Germany, France, Sweden, the U.S.A., the U.S.S.R. and Great Britain, extensive tests have been made on corona losses and radio interference. The use of four-conductor bundles is being actively investigated. High-altitude operation, where corona loss is even more severe than at sea level, are being undertaken in the U.S.A.

Another high-voltage overhead-line problem is that of lightning flashovers, and much research still needs to be carried out in this field. For example, the first 345 kV lines commissioned in the U.S.A. were subject to considerably greater lightning troubles than was anticipated, whereas British experience with their 275 kV super-grid system was the reverse. Much field work on lightning problems, aided by automatic recording apparatus of the most modern kind, is now in progress. Lightning troubles are best attacked with the aid of reliable statistics, and these have been only sparsely available in the past. Lightning-arrester design will probably improve rapidly, since the non-linear characteristics of the resistance elements are likely to be made more controllable, as a byproduct of semiconductor research.

During the next fifty years, transmission voltages are not likely to follow the same upward tendency as in the last half-century. Swedish calculations, in particular, have shown that the curve of overall economic advantage plotted against increased voltage begins to level off above 500 kV. In other words, the advantages gained by moving from 400 kV to 580/600 kV are very much less than the advantages to be secured by changing from 220 kV to 400 kV. It seems unlikely that the enormous extra cost of insulation for transformers, switchgear and substations, as well as for the line itself, could be offset by power-transfer advantages, when considering an extension of a 200 kV or 300 kV step above the present levels.

The use of series capacitors at substations along the length of transmission lines has gradually spread during the last decade, and is likely to become a much more prominent feature of future transmission networks. These devices, in turn, bring intractable switching problems, but solutions are being actively pursued.

There is a further fundamental problem facing an increasing number of the world's transmission engineers. Routes for any sort of overhead line are becoming increasingly difficult to find in industrial countries, and the type of tower needed for 600 kV lines, possibly 200 ft. high, will arouse public resentment to an even greater degree than before. It is not only aesthetic reasons that provoke resentment. The sterilisation of wide tracks of tree-growing land, the hindrance to agricultural operations, the difficulties encountered when maintenance has to be undertaken on routes crossing highways, railroad tracks and navigable waters, all give rise to severe difficulties. A 132 kV substation in the English countryside which twenty years ago had four lines radiating from it, now has fourteen, and the value of the agricultural land in the vicinity has sharply deteriorated. In the northern suburbs of London there is a proposal to erect a 275 kV substation close to a colony of middle-class houses, and a violent clash of interests is expected.

In the U.S.A., where it might be thought that with so vast a territory right-of-way problems would be relatively easy to solve, there is recent news of very strong opposition to certain power-line proposals. The solution of undergrounding is economically impossible at present, when it would cost about sixteen times as much to lay a given high-voltage power route underground as it would to carry it on towers.

The methods that may be adopted in the next few decades include the use of direct current, to give much greater power capacity on a given overhead-line route, and to allow for voltages up to 1,000 kV or even higher; and the evolution of plastic-insulated underground cables which will be significantly cheaper than the present designs. In Canada, attention is being directed to the possibility of using direct-current cables laid on top of the ground. This scheme has been discussed in other parts of the world, including Sweden, and a new approach to power transmission, with new techniques for guarding the cables and for enabling them to bridge inequalities in the surface and natural obstacles may be evolved. The use of direct current will undoubtedly spread, as the schemes at present under construction bring fresh knowledge of the techniques involved. The cross-Channel scheme, which should be in commission by 1961, will provide a fund of operating experience on a major project, involving a non-synchronous coupling between two very large networks.

Conclusions

During the next fifty years, the electrical engineer concerned with hydro-electric power generation and transmission will probably find that his main preoccupations will be with light-current equipment of great complexity, needed to control his unattended hydro stations and to co-ordinate and regulate the system as a whole, and with high-voltage power transmission, to enable him to bring in the power from yet more-remote water-power sites to the industrial areas. Unlike the engineers concerned with nuclear or thermal stations, where in the last resort the station can be erected near the load, the hydro-electric engineer cannot move the waterfall; he must carry his product electrically and therefore he is likely to remain in the vanguard of power-transmission progress.

The Twenty-First Anniversary of The Association of Short-Circuit Testing Authorities. The Association of Short-Circuit Testing Authorities was incorporated on December 7, 1938, and to mark the occasion of its twenty-first anniversary a handsome brochure has been produced. This reviews the history of the Association, touches on some of the personalities connected with its formation and gives a brief account of the testing stations, some of the research work carried out, the types of equipment tested, and the highly specialised instrumentation used for these tests.

Conference on the Protection of Hydro-Electric Plants Against Corrosion

The First International Conference on the Protection of Hydro-Electric Plant and Equipment against Corrosion was held at Belgrade, and its proceedings are briefly summarised by Dr. Ing. Fran Podbrežnik

THE rapid tempo of construction of hydro-electric power plants has brought to the fore the necessity to solve problems of their protection and to find efficient means to preserve materials built in to their structures. An international conference—the first of its kind—was therefore organised by the Yugoslav Association for the Protection of Materials. The Conference was held last September in Belgrade, and the subjects discussed were the protection of concrete dams and auxiliary concrete structures, sluice gates and chambers, tunnels, pressure pipes, hydro-mechanical equipment (turbines, inlet and outlet parts and mechanisms), electrical equipment and accessories, high-voltage transmission lines and other electrical equipment.

Durability of equipment greatly influences the economy of power plants. Proper maintenance and preventive protection of the equipment in turn affect durability and play a major role in economy of operation. These resolve themselves into questions of management, but there are countless other factors, coming under the subject of protection, which profoundly influence durability and economy of operation, but which are less known and in everyday practice overlooked. Greater attention should therefore be devoted to these factors in order to achieve maximum economy and reliability.

Rapid construction of major hydro-electric power plants entails matters such as economy of construction materials, the use of new construction materials, and in turn the application of new protective measures to preserve these materials. Then again, the increasing pollution of water and atmosphere by industrial acids and wastes undoubtedly affects the resistivity of materials used for hydro-power installations. Today, much is being done to use all the available industrial and technical materials more sparingly and to attain satisfactory results without unnecessary outlay. These new elements call for additional efforts to ensure better protection of future and existing hydro-power equipment and installations.

Much hydro-power equipment is either permanently or periodically submerged, and must therefore be protected against corrosion and erosion caused both by water and by the atmosphere. Furthermore, items such as cranes are placed in the open above a great volume of water and are directly exposed to damp. Many problems of protection are encountered when constructing the supply conduits to the generating sets. In addition to corrosion we have damage caused by cavitation and erosion. Likewise, specific problems present themselves in cases where underground waters have to be sealed off from tunnels and canals. Similar questions arise of protection of the machines and other mechanical and electrical equipment, including the transmission lines.

It was to problems of the nature outlined above that the papers submitted to the Conference were devoted.

Organisation of the Conference

At the First International Conference some 80 experts from abroad and 200 participants from Yugoslavia were present. Lectures and discussions were held in four languages: English, Russian, French and German. The opening ceremony was held in the Science Academy at Belgrade, and the Working Groups held their meetings at the University. The second part of the Conference took place at Maribor, and draft conclusions and resolutions were discussed. A programme of visits to factories and hydro-electric power plants in Yugoslavia was also organised.

The technical programme was divided into the following five Working Groups:

Working Group I—Protection of Structures.

Working Group II—Protection of Hydro-mechanical Equipment.

Working Group III—Protection of Electric Equipment against Corrosion.

Working Group IV—Protection of Transmission Equipment against Corrosion.

Working Group V—Various Problems Relating to Corrosion Control and Prevention.

Summaries of Some of the Papers

At the Conference 74 papers were submitted and discussed, and a few of the principal ones will now be summarised.

DETERIORATION OF CONCRETE IN NORWEGIAN DAMS. *By Kristen Friis, Consulting Civil Engineer—Oslo*

The Norwegian Society of Engineers appointed in 1926 a committee for studying the deterioration of concrete in Norwegian dams. Their conclusions were briefly as follows:

(a) The majority of Norwegian dams, especially the older gravity dams, have more or less deteriorated. One of the largest dams, situated in the high mountains, was absolutely watertight when it was brought into service in 1916. In 1930 the leakage was approximately 1,000 lit. per sec. and the dam had to be rebuilt.

(b) This deterioration was mainly due to the fact that the water, especially in the Norwegian high-mountain streams, is very acid, with a *p*H value down to 5·6 and an alkalinity of only 7 mg. per lit.; it consequently dissolves the lime in the concrete. The water thus enters the construction through

cracks in the surface due to shrinkage and to temperature variations.

(c) The committee recommend building of reinforced-concrete dams (as Ambursen dams, multiple-arch dams, buttress dams, etc.) instead of gravity dams, to avoid such surface cracks.

(d) For repair, either an elastic cover can be put on the surface, the dam can be faced with an elastic reinforced-concrete wall, or it can be treated with cement injection, especially when it is difficult and expensive to put the dam out of operation.

ORGANISATION OF CORROSION CONTROL IN HYDRAULIC POWER PLANTS. *By Ing. Ivan Kotnik—Ljubljana*

A survey is made of the reasons for corrosion damage that has occurred in hydro-electric plants. A study of these reasons shows that the bulk of damage can be prevented by soundly organised work on the protection of metal parts against corrosion. At the request of owners and manufacturers of equipment, a draft of standard prescriptions has been made out specifying what should be done so far as permanent protection and corrosion control are concerned.

PROTECTION AGAINST FIRE FOR TRANSFORMERS. *By Dott. Ing. Angelo Bonomo—Turin*

In this paper two systems of protection are proposed using water or CO_2.

CORROSION CONTROL IN WATER-POWER PLANTS. *By Dott. Ing. Angelo Bonomo—Turin*

The paper shows the conditions to which metallic and mural constructions are submitted during service. Evidence is given of the indispensability of a maintenance schedule to guarantee the efficiency and best output for all parts of the plant. Some suggestions are made on turbine repairing, varnish application, and tests.

CRITERIA AND METHODS OF CHOICE OF AN ANTI-CORROSIVE COATING FOR THE PROTECTION OF HIGH-VOLTAGE STEEL TOWERS. *By Ing. Tadeusz Biestek—Warsaw*

Two methods of protection of transmission towers are regarded as the most suitable: hot-dip galvanising and painting. A period of 30 years is accepted as an effective time of protection. An economic analysis of costs, including those of materials, manufacture, investment and conservation, is made, which shows that although the initial cost of producing zinc coatings by the hot-dip process is higher than painting, its long-term cost is much lower. This remains true when investment costs are taken into account. Furthermore, it is unnecessary to close down the line for painting.

AGEING AND DETERIORATION OF IMPREGNANTS FOR CAPACITORS. *By Ing. H. Elsner—Fribourg, Switzerland*

After some introductory remarks on liquid impregnants for capacitors, the author discusses impregnating oils as used for modern high-voltage capacitors and considers their properties, advantageous and otherwise. These properties are appraised by means of tests and measurements according to national and international standards in order to determine the suitability of the oils as insulating media. Ageing resistance and absorption characteristics of the impregnant are both of great importance for capacitor life and performance. These problems are now being studied by a special committee of CIGRE.

CORROSION PROBLEMS OF TRANSFORMERS. *By Prof. Dr. Ing. Karl Potthoff—Stuttgart*

The problem of corrosion of a transformer may be divided into an external and an internal one. Air-cooled transformers with an output of more than 10,000 kVA must have very large surfaces—up to 1,000 sq. m. and more. Because the thickness of the sheets of the radiators is small, the task consists in producing a thin protective coating which does not disturb the cooling effect and protects the sheets for many years. Zinc and special paintings give this protection.

Corrosion in the interior of the transformer affects the oil and insulating material. By choosing a special quality of oil, a conservator and drying equipment are sufficient to protect the oil.

LOW-PRESSURE CARBON-DIOXIDE FIRE EXTINGUISHING SYSTEM. *By J. D. Shapland—London*

Whereas the use of high-pressure CO_2 systems for fire protection has been designed and installed for over 30 years, the use of the low-pressure system is a recent development. Only one pressure cylinder is required and the system thus becomes more economical as the quantity of CO_2 required for the risk increases, and is an economical proposition above about 1,500 kg. of CO_2.

The CO_2 is stored in an insulated pressure cylinder at 20 atmospheres at a temperature of $-10°C$. held by an external refrigerator. The low-pressure system is ideally suited for the protection of large electrical generating equipment, as it is capable of supplying relatively large quantities of CO_2 gas over long periods of time.

The paper deals with the following main headings: Physics and chemistry of CO_2 as far as fire extinguishing is concerned. Description of typical low-pressure CO_2 installation. Basic engineering calculations for system, both total flooding and extended discharge. Application of above data for the protection of electrical generators and distribution equipment.

CORROSION OF STEELWORK IN WATER-POWER PLANTS. *By Dr. Herbert Man—Wels, Austria*

This paper outlines the difficult corrosion problems in regard to steelwork in water-power stations in the light of their importance to the national economy. Modern measures against corrosion in steelwork and pipelines are outlined. Very effective cleaning operations are necessary such as sandblasting, flame-cleaning, etc., and their value is discussed. Important advances have taken place in the technique of producing coatings, linings and enamels. It is pointed out that processed coal-tar-based products are to be preferred in regard to their qualities in this field.

EXAMINATION, CONTROL AND METHODS OF APPLICATION OF COAL-TAR PAINTS AND ENAMELS FOR STEELWORK. *By Dr. Wilhelm Stroh—Vienna*

Hints are given as to how anticorrosive protection with paints can be effected, e.g., how to prepare the surface; conditions to be fulfilled in regard to humidity, temperature, steel surface and derusting; and examination of the paint film in reference to thickness, porosity, adhesion and penetration.

The Summation Curve - Its Establishment and Application in Hydrology

The author explains how summation curves can be used in computing many problems of river regulation for power and other purposes

By J. OTNES, M.N.I.F.*

THE River Flow Summation Curve, also termed the Mass Curve, is one of the most suitable methods for studying the effect of various storage capacities provided on a river and for the utilisation of water in its practical aspects. In this article the method of establising a summation curve will be explained. Some of its applications will also be described. These are so numerous, however, that only a few examples can be dealt with in a short paper of this type.

The Hydrological Branch of Norges Vassdrags og Elektrisitetsvesen (Norwegian Department of Watercourses and Electricity) has for years applied calculations based on summation curves for a multitude of practical purposes. In basins with a complex system of reservoirs for utilisation in one or more power stations, far-reaching conclusions have been arrived at by computations derived from one or more summation curves. A standard system for the application of these curves has gradually been developed, and a few of the examples and methods which are explained in this article have been taken from the current practice in this office.

The method has been applied on investigations in the Rufiji basin, Tanganyika, where hydrological observations are available for only a very few years. This article explains how a summation curve can be established under such conditions, and what results can be obtained with only a very few years of river-flow records.

NOTATIONS:

q = rate of river flow, cusecs, acre ft. per day (m^3/sec.).
$\bar{q}$ = average rate of flow.
q_c = curve constant.
q_r = regulated flow .
$q_{r(m-n)}$ = regulated flow from year m to year n.
Q = volume of water, acre ft. (m^3).
S = reservoir capacity, acre ft. (m^3).
$S_{(m-n)}$ = reservoir capacity required from year m to year n.
t = time, seconds, days.

Basic principles

Applied to hydrology, the summation curve gives the accumulated discharge for a river-gauging station from a set time which is usually chosen as at the commencement of the observations. Daily discharges are added together in a suitable unit, selected in accordance with the size of the run-off. Commonly used units are millions or thousands of cubic metres, acre feet or cubic feet. The curve is plotted with time t as abscissa and the accumulated discharge Q as the ordinate.

The curve is an integral curve, and if q denotes the rate of discharge, Q can be expressed as follows:

$$Q = \int q\,dt \qquad \ldots (1)$$

From this can be derived

$$q = \frac{dQ}{dt} \qquad \ldots (2)$$

The rate of discharge is thus expressed by the slope of the tangent at any point of the curve. The average discharge between two arbitrary points on the curve (t_m, Q_m) and (t_{m+1}, Q_{m+1}), will be accordingly:

$$q = \frac{Q_{m+1} - Q_m}{t_{m+1} - t_m} \qquad \ldots (3)$$

Fig. 1 shows three successive "water regulation years." This is a time unit commonly used in hydrology when analyses are carried out on these curves. A water regulation year has no fixed length. It may vary from year to year and may even exceed a year depending upon the designed degree of regulation and the annual distribution of run-off. It may therefore be defined as a period of time from the beginning of a regulation in one year to the end of that regulation.

In Fig. 1, a line is drawn from the first minimum turning point (t_1, Q_1) to the fourth (t_4, Q_4). This represents the average discharge for the three complete regulation years and can be expressed as follows:—

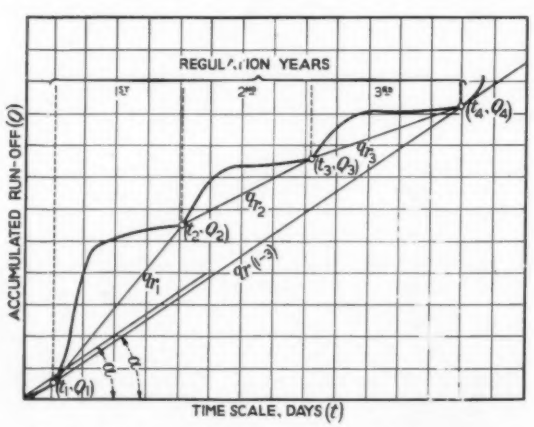


Fig. 1. Three successive water regulation years

* Chief Hydrologist to the Rufiji Basin Survey, Tanganyika, Food and Agriculture Organisation to the United Nations.

$$q = \tan \alpha = \frac{Q_4 - Q_1}{t_4 - t_1} \qquad \ldots (4)$$

At all points where the tangent to the curve is parallel to this line, the discharge is equal to the three-years average. A steeper slope of this tangent indicates a higher discharge than the three-years average discharge and *vice versa*. It will be evident that if the river goes dry, the curve will be horizontal during that period.

If the observation period is two or three years only, the curve can be plotted as shown in Fig. 1, but if data extend over a longer period, the curve cannot be fitted within the limits of the paper. In such cases it can be plotted as the accumulated sum of the deviations from the mean. The main trace of the curve will thus be horizontal and it can be plotted on a roll of graph paper.

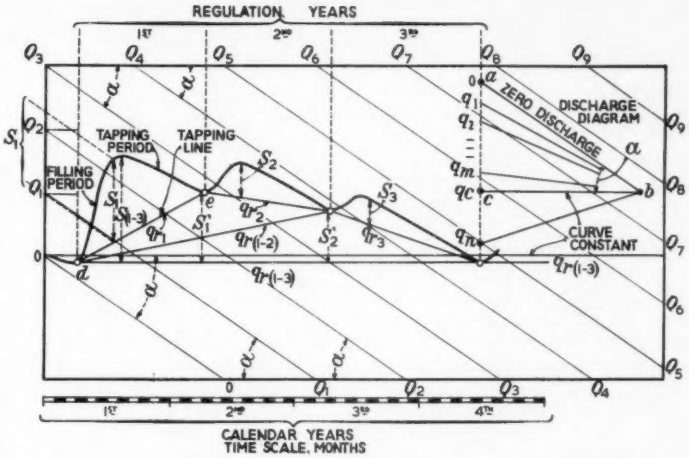


Fig. 2. The summation curve of Fig. 1 transferred to the skew system

If possible, a summation curve should be plotted in accordance with a long-term average $\bar{q}$. If only a few years of observation are available when the curve has to be established, an average for a longer period should be computed indirectly in comparison with run-off in adjacent catchments or with rainfall. An average will always vary slightly as data for new years come into the calculations, and for this reason it is more correct to signify the applied figure representing the up-to-date actual average as the "curve constant" q_c. If q_c is carefully selected it will always be close to the current average value, and the plus and minus deviations will be of about the same order from year to year. In this manner a summation curve covering a period of 50 years or more can be plotted on the same roll of graph paper. The run-off conditions for the station in question are clearly illustrated by this curve. Storage capacity requirements year by year, or for longer periods, can easily be visualised. Studies and graphical calculations can be made directly on the curve.

If no modern electric calculating machines are available, the computations of daily divergencies from an average is laborious for a long period of observations. Another method of obtaining the same result is to plot the curve to a skew co-ordinate system, Fig. 2. The same years as on Fig. 1 are used for the example and all the ordinates are turned through an angle $-\alpha$ from their origin. The line representing the curve constant is also horizontal on this graph.

By transferring a summation curve from the right-angled co-ordinate system, Fig. 1, to the skew system, Fig. 2, all points on the curve are transferred vertically. The time scale thus remains horizontal and unchanged.

The discharge diagram, Fig. 2, is established from a right-angled triangle, *abc*, as follows: The hypotenuse, *ab*, is parallel to the skew ordinates and represents zero discharge. The side *bc*, is horizontal and gives the curve constant q_c. If the side *ac* is divided into q_c units, the rate of flow is expressed by lines drawn from *b* to these points respectively. It is practical to utilise the graph-paper division and to draw some standard lines representing round numbers of discharge (q_1, q_2 ..... q_m). The line *ac* can be extended and by applying the same scale below *c* as above, discharges higher than q_c can be calibrated, q_n.

In practice the skew ordinates are drawn only for an equal round number of river run-off, Q_1, Q_2, Q_3, etc. (Fig. 2) and the curve is plotted by applying an appropriately scaled ruler. Five-day progressive totals are invariably used and run-off details will be sufficiently expressed.

When a curve is started and new observations are received from the field, these discharges should be added to the previous total and the curve extended. The graph paper should last for years and should therefore be as strong as possible. A transparent tracing cloth is preferable. Copies of the curve can then be taken at any time and the roll easily stored in shelves retained for this purpose. Inches divided into 20ths is a suitable graph division, with $\frac{1}{10}$ths or $\frac{1}{20}$ths representing two days in the horizontal direction.

The vertical scale must be selected according to the size of the run-off and should preferably be such that α is as near 45° as is possible. If α is too small the curve becomes "flat" and the necessary accuracy by graphical computations may be difficult to obtain. On the other hand if α is too great it will be difficult to keep the curve inside the scaled area for any length of time.

The maximum possible steady flow over the first regulation year is signified by q_{r1} (Fig. 2), the size of which can be determined by a parallel transfer to the discharge diagram. An effective reservoir capacity of S_1 is required for the maintenance of this flow. The latter is expressed by the maximum distance between the curve and the "tapping line." The time between the first tangent point *d* and the day of maximum reservoir capacity is called the "filling period," and the time between this day and the second tangent point *e* when the reservoir is again empty, the "tapping period." For the second and third regulation years the corresponding flows are expressed by q_{r2} and q_{r3}. The storage capacities required are given by S_2 and S_3.

When more years follow each other as in Fig. 2, it is possible to keep a steady flow over longer periods. The maximum possible steady flow over the first two years is $q_{r(1-2)}$ and for the three years $q_{r(1-3)}$. The

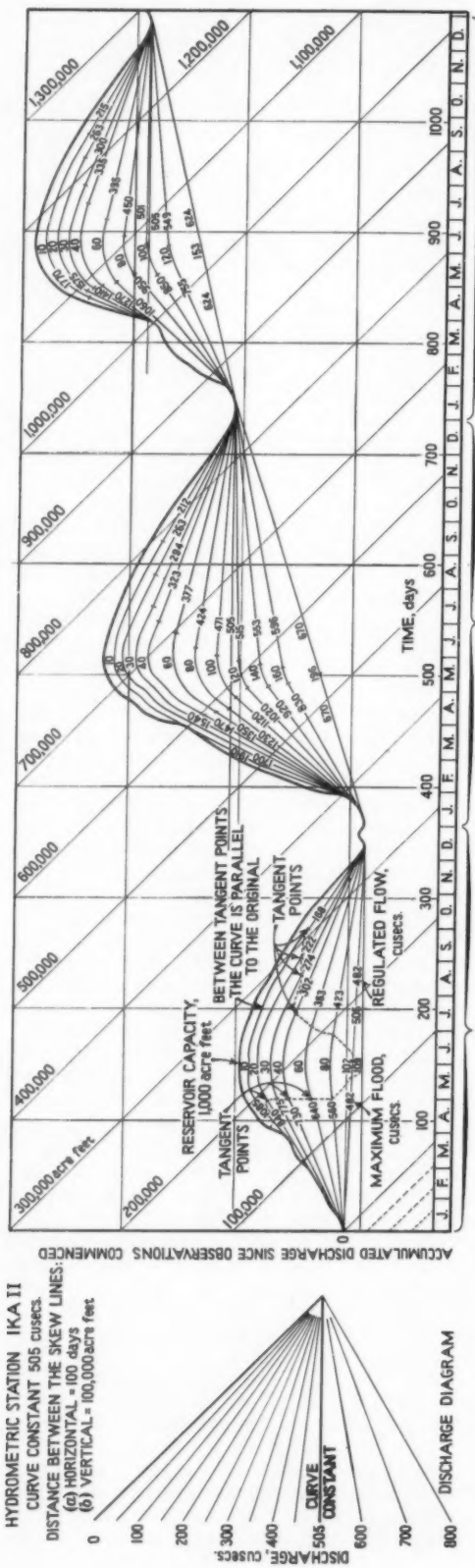


Fig. 3. Method of graphical calculation when the reservoir capacity is taken as an independent variable

maximum effective reservoir capacity required in the latter instance is $S_{(1-3)}$ which has to be filled during the first year. A volume of S_1' must be kept back in the reservoir from the first to the second regulation year and correspondingly S_2' from the second to the third year.

Example on Establishment of a Summation Curve

Chosen as an example is the summation curve for Igawa hydrometric station on the Mbarali River, Rufiji basin. On the date of establishment, observations were available for three hydrological years only, and a suitable curve constant was determined in comparison with rainfall over the catchment area. The data are as follows, all given in acre feet:—

	Rainfall	Run-off
1954–55	1,067,000	336,999
1955–56	1,408,000	494,410
1956–57	1,308,000	438,543

There is a reasonable correspondence between these rainfall and run-off data. The average rainfall in the seventeen-year period since 1940–41 is 1,130,000 acre feet which gives an average yearly run-off of approximately 365,000 acre feet, equivalent to a discharge of 505 cusecs over the year.

If the vertical distance between the skew ordinates is selected as 100,000 acre feet, the horizontal distance between them will be 100 days. If the scale is selected as one inch to 20,000 acre feet and one-tenth to two days, α equals 45° which is very convenient for plotting. The curve is given to a reduced scale in Fig. 3.

In most instances the horizontal distance will not work out to be a round number of days, as for the Igawa station. For convenient plotting, it is therefore recommended to round off the number of days as first computed and adjust q_c thereafter.

The basic figures for the Igawa summation curve will be:

Curve constant q_c: 505 cusecs (17-year average).
Vertical distance between skew lines: 100,000 acre feet.
Horizontal distance between skew lines: 100 days.

The actual summation of discharges is done on a calculating machine which types the figures. Six months can be calculated on the same sheet of paper and the records kept in an ordinary computation file for the station. An extract of the summation for Igawa is given for the first half of 1956 in Table 1, discharges being given in acre feet. Progressive run-off totals are calculated for five-day periods and at the end of each month (indicated thus *).

Application of Summation Curves

REGULATION CURVES:

The "yearly regulation curves" can be established from a summation curve. These curves show the resultant regulated flow for any *effective* reservoir capacity located upstream of the point under consideration. The regulated flow may be defined as the minimum flow in the regulation year when storage is utilised for obtaining a flow as even as possible at a given point. A yearly regulation curve commences at the point of minimum discharge and ends at the point of average discharge over the total regulation year. In certain instances the regulation curves can be extended for regulation studies over further years.

It does not matter which of the units—reservoir capacity or discharge—is chosen as an independent variable for the purpose of calculation. On the extract form, Table 2, the reservoir volumes are entered in

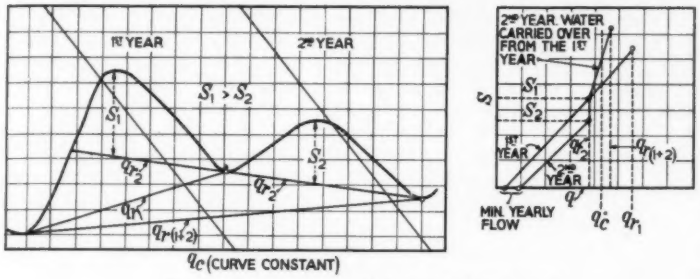


Fig. 4. An interrupted regulation curve

the first column and the corresponding regulated flows are calculated year by year and have been entered in the appropriate places. The data are most conveniently computed graphically and if the curve scale is not too small, reasonable accuracy will be obtained. The calculations can be checked arithmetically from the accumulated discharge similar to that given in Table 1.

When the reservoir capacity is used as the independent variable, the graphical calculations are performed by taking parallel transfers of the curve as shown in Fig. 3. The tapping lines are drawn as tangents to the original summation curve and to the parallel curves respectively and are thereafter calibrated by a transfer to the discharge diagram.

The regulation curves are established without taking into account evaporation losses from the surface of a reservoir. This is a special factor which has to be deducted from the storage capacity in the tapping period. If this is done the curves are still valid. If a lake is utilised for storage, evaporation from its surface is automatically included in the discharge observations and cannot therefore be deducted again. It is presumed that the evaporation from a lake is about the same in a natural as in a regulated state. The only practical difference may be in the evaporation from a random strip due to changes in water level from natural conditions.

The second part of Table 2 gives the length of the tapping period. This is an important factor when loss of water by evaporation has to be estimated. For lower grades of regulation the loss of water during the filling period is of little consequence. Beginning with a full reservoir, evaporation must be calculated from the time when tapping commences and until the regulated flow is equivalent to the natural flow of the river. The length of the tapping period can be taken directly from the summation curve but more accurate results are obtained when it is taken from calculations similar to those in Table 1.

Seepage from a reservoir is also a special factor which, in certain instances, will lower the effective storage capacity. If at all possible, adjustment should be made for this loss. In most cases, however, a great deal of the percolated water can be reckoned as returning to the river downstream of the reservoir, and the practical adjustment will not be so great as at first assumed. In quite a few instances it can also be disregarded, but this depends upon local factors and must be studied in each particular case.

The third portion of Table 2 gives figures for the regulation curves in percentage of the average. Storage capacity is calculated as a percentage of the yearly average volume of water going into the river, and the regulated flow is given accordingly in percentage of the average rate of flow. This is done in order to facilitate extended use of the regulation curve. Experience has shown that catchments of approximately the same hydrological character produce nearly equivalent regulation curves when expressed in percentage values. This often permits the use of the regulation curve in an adjacent area and for other points on the same river.

The yearly regulation curves are always continuous. For parts of the curve where the tapping period is constant, the regulation curve is linear. The tapping period will, however, as a rule increase with the storage, resulting in a corresponding curvature of the regulation curve. This implies that each addition to the storage capacity will always give a progressively smaller increase in the regulated flow.

TABLE 1.—EXTRACT OF THE CALCULATIONS OF PROGRESSIVE RUN-OFF TOTAL FOR MBARALI AT IGAWA, 1956 (Discharge in Acre Feet)

January	February	March	April	May	June
350317*	419039*	529201*	611560*	697278*	739462*
474	1664	2303	3330	1972	896
768	1514	2637	5463	1898	890
727	3687	3014	4557	1843	878
3200	9686	2968	5076	1798	866
948	3788	2855	5358	1770	860
356434*	439378*	542978*	635344*	706559*	743852*
967	4024	2616	5209	1834	846
864	3944	2395	3753	1665	846
2232	3997	2375	3177	1614	834
792	3379	3153	2822	1539	834
1291	3971	3464	2616	1440	834
362580*	458693*	556981*	652921*	714651*	748046*
711	3763	3142	2426	1432	834
565	3083	2659	2323	1408	846
769	1953	2283	2283	1424	834
1259	2509	2344	2067	1432	834
560	2344	2144	2028	1392	810
366444*	472345*	569553*	664048*	721739*	752204*
642	2855	1981	1953	1290	792
625	2232	1943	2067	1259	786
2888	4211	2637	2193	1259	792
3106	5930	3439	2115	1259	792
5449	10015	3813	2028	1199	792
379154*	497588*	583366*	674404*	728005*	756158*
3223	4990	2854	2028	1148	786
3788	3003	2447	2702	1097	745
2957	2900	2313	3642	1056	720
2077	2833	2364	2174	1126	720
1972	2344	2313	2067	1104	733
393171*	513658*	595657*	687017*	733536*	759862*
3637	2115	2283	1972	1090	733
10532	7142	2385	1934	1063	733
3366	3318	1981	2125	967	692
3366	2968	2811	2212	942	681
2900	529201*	4376	2018	942	642
2067		2067	697278*	922	763343*
419039*		611560*		739462*	

When regulation curves are computed over more years, an interrupted curve is often obtained. This occurs as shown in Fig. 4, when a year with favourable conditions involving a lower grade of regulation follows a less favourable year. The second year gives a maximum regulated flow of q_{r_2} requiring a storage capacity of S_2. The same regulated flow during the first year requires a reservoir capacity of S_1. It is implied here that $S_2 < S_1$, and if the water is carried

over from the first to the second year, the regulation curve will get an interruption corresponding to the difference $S_1 - S_2$ at a flow of q_{r2}.

When water is carried over from one year to another, the calculations are most conveniently tabulated as in Table 3. This shows four selected years from Röldalsvatn hydrometric station, Norway. On Fig. 5, the same years are reproduced to a reduced size.

Regulated discharge, expressed in cu. m. per sec., is the independent variable here, and the storage capacities in million cu. m. required for keeping this flow, is entered in the yearly columns. The curve constant is 36 cu. m. per sec. To be able to maintain this flow during the year 1922–23 and 1923–24, water had to be brought forward from previous years and reservoir capacities of 688 and 750 million cu. m. were required respectively. The filling of these reservoirs had to commence in 1920–21, which is indicated by arrows in Table 3. The maximum reservoir capacity was required in 1921–22 to provide for the water requirements in the following two deficient years.

The average discharge over the regulation years and the corresponding reservoir capacities are listed at the foot of the table. As will be observed from Fig. 5, the year 1923–24 gets an interrupted regulation curve at a flow of 34 cu. m. per sec., when water is carried over from previous years. This is entered in Table 3, with a small circle between the years 1922–23 and 1923–24, indicating that the tapping line is a tangent to the curve here.

The regulation curves can be used directly when an increased steady flow is the object for regulation. This is very often the case in power-plant development. For irrigation purposes rainfall and agricultural conditions must also be taken into consideration and an uneven flow may often be found to be desirable and more economical. The appropriate variations of flow must then be considered within the limitations of the reservoir capacities. Estimates of this nature can be carried out directly on the summation curve.

When observations are available for a great number of years, the basic data for the regulation curves can be grouped in various ways. Under such conditions the establishment of the "median curve" will be found to be practicable. The available years of observations are then grouped into two equal parts of which the one half (50%) shows more-favourable and the other half (50%) less-favourable regulation conditions than the median curve. This curve is applied in cases where a water deficit can be permitted in half the number of years.

An average curve can also be used in certain instances, but it has its disadvantages. Two slightly different curves are derived depending upon whether the reservoir capacity or the regulated flow is shown as an independent variable.

The "most-unfavourable regulation curve" is very important in many instances, when great safety is required as in the case of a water-supply scheme. This is determined as the upper enveloping curve for the total series of available data.

Depending upon the degree of safety required in water estimates, various kinds of regulation curves can be established. A 90% safety curve is commonly used in Norway, where this system has been developed. This means that the power plant in question, under the suggested river regulation, will not receive enough water in one out of ten years to yield full capacity.

The median curve, the most-unfavourable curve, and other percentage safety curves will only be established up to average discharge ($\bar{q}$ or 100%). There is no point in extending these curves further. Over a long period the regulated discharge cannot exceed the average discharge.

Flood Reduction Curves

Following the same principles as for the regulation curves, the flood reduction curves for a gauging

TABLE. 2.

REGULATION EFFECT OF VARIOUS STORAGE CAPACITIES.

RIVER MBARALI STATION IGAWA NO. IKA. 11. CATCHMENT AREA 619 SQ. MILES.

AVERAGE YEARLY RUNOFF: 365,000 ACRE FEET: 505 CUSECS.

STORAGE CAPACITY (S)	REGULATED FLOW DURING THE DRY SEASON CUSECS. (Q_r)					LENGTH OF TAPPING PERIOD IN DAYS.					PERCENTAGES OF AVERAGES. STORAGE CAPACITY. %	REGULATED FLOW, %.				
ACRE FEET	1955	1956	1957	1958	1959	1955	1956	1957	1958	1959		1955	1956	1957	1958	1959
0	68	105	115			0	0	0	0	0	0	13.5	20.8	22.8		
5,000	133	185	184			69	76	77			1.4	26.3	36.6	36.4		
10,000	168	212	215			76	93	89			2.7	33.3	42.0	42.6		
15,000	199	237	242			93	105	110			4.1	39.4	46.9	47.9		
20,000	222	263	263			102	126	116			5.5	44.0	52.0	52.0		
30,000	274	294	300			116	160	138			8.2	54.3	58.2	59.4		
40,000	302	323	335			152	183	157			11.0	59.8	64.0	66.3		
60,000	363	377	385			164	191	175			16.4	71.8	74.6	78.2		
80,000	423	424	450			169	216	197			21.9	83.7	83.9	89.0		
100,000	477	471	501			191	221	203			27.4	94.4	93.3	99.2		
120,000		515	549				227	208			32.9		102.0	108.7		
140,000		553					242				38.4		109.5			
160,000		596					248				43.9		118.0			
	482	670	624			191	253	215				95.2	132.7	123.5		
	102,000	196,000	153 000			—	—	—	—	—		28.0	53.7	41.9		

station can be established. These relate the size of effective reservoir capacity on a river to the corresponding maximum flood obtained under regulated conditions. It is then presumed that all reservoir capacities are utilised for cutting the flood peaks off in such a way as to get the maximum flow as even and as small as possible at the station under condition.

The computation of regulated floods is conveniently done graphically, as explained on the summation curve for Igawa, Fig. 3. In this instance, the tapping lines are drawn as tangents to the original summation curve at the time when filling commences and at the same time as tangents to the parallel curves drawn at appropriate intervals. The distance between the original curve and the parallel one denotes the reservoir capacity under consideration. At the second tangent point, this particular reservoir is filled and will remain full until tapping commences with the derived regulated flow, as already explained. The sizes of various reservoir capacities in question are marked on Fig. 3, at the time when the reservoir is full.

TABLE 3

Regulated Discharge	Reservoir Capacity Required			
	1920–21	1921–22	1922–23	1923–24
m^3/sec.		million m^3		
5	8	24	13	38
10	50	98	97	107
15	111	172	195	183
20	200	252	302	265
25	292	333	410	357
30	386	421	523	453
36	500	524		
	←	688	663 →	
	←	750		570 →
Average discharge ...	41·6	38·8	31.0	34.0
Reservoir capacity required	608	566	545	
		←	610	o— 528 →

Extracts from the curve are listed in Table 4. The values in the second part of Table 4 are computed in percentage of the same yearly average as the regulation curves, *vide* Table 2. The purpose of the relative computations is for an extended use of the data. When a flood reduction curve is expressed as a percentage, it can, to a certain extent, also be applied in other catchments and for other points on the same river, provided hydrological conditions are more or less identical. A special table can be made for the length of the filling period if required.

General Considerations

In Fig. 6 are plotted the regulation curves and the flood reduction curves for Igawa. As will be seen the three regulation curves show a very small difference. This is due to the fact that there is no appreciable rainfall influencing the river flow during the dry season, and that the river depletion curves thus become approximately parallel and of about equal length from year to year. The regulation curves are plotted up to the point showing an even flow throughout the whole regulation year. The flood reduction curves vary more from year to year and as a result of this, estimates of flood control become more uncertain. It is recommended that the most unfavourable curve be chosen for safety.

It can be mentioned that 1956 was a very heavy rainfall year, not only for the Mbarali area but more or less for the whole south-eastern part of Tanganyika. At many stations the 1956 rainfall is the maximum ever observed. The flood reduction curve for this year can therefore be considered as very unfavourable and be applied in calculations on flood control.

When a reservoir is situated in the headwaters of the catchment and is a great distance from the utilisation point, the filling possibilities must be studied separately and carefully. If such a reservoir can be filled, its actual location should not really matter for the corresponding regulation curve. In some areas, however, the loss of water in the dry season will increase as the river flow increases. This merely means that the losses from the stretch of the river considered will be higher when more water is available. This factor must be studied separately.

The flood reduction curves will only apply if the actual flood contribution from the partial unregulated sub-catchment between the reservoir and the utilisation point does not exceed the computed regulated flood. For this purpose a reservoir can contribute only to the extent of regulation of its own catchment.

TABLE 4.—MBARALI RIVER AT IGAWA
Regulation effects of various storage capacities.

Storage capacity acre/ft	Maximum Flood after Regulation. cusecs.			Percentages			
				Reser-	Regulated Flood		
S	1955	1956	1957	voir	1955	1956	1957
0	3,100	9,300	6,800	0·0	614	1,842	1,347
10,000	1,085	1,910	1,770	2·7	215	378	350
20,000	840	1,700	1,575	5·5	166	337	312
30,000	775	1,540	1,410	8·2	153	305	279
40,000	730	1,470	1,270	11·0	144	291	251
60,000	640	1,350	1,060	16·5	127	267	210
80,000	560	1,230	950	21·9	111	244	188
100,000		1,120	850	27·4		222	168
120,000		1,020	755	32·9		202	150
140,000		920		38·4		182	
160,000		830		43·9		164	
	482	670	624		95	133	124
→	102,000	196,000	153,000	→	28·0	53·7	41·9

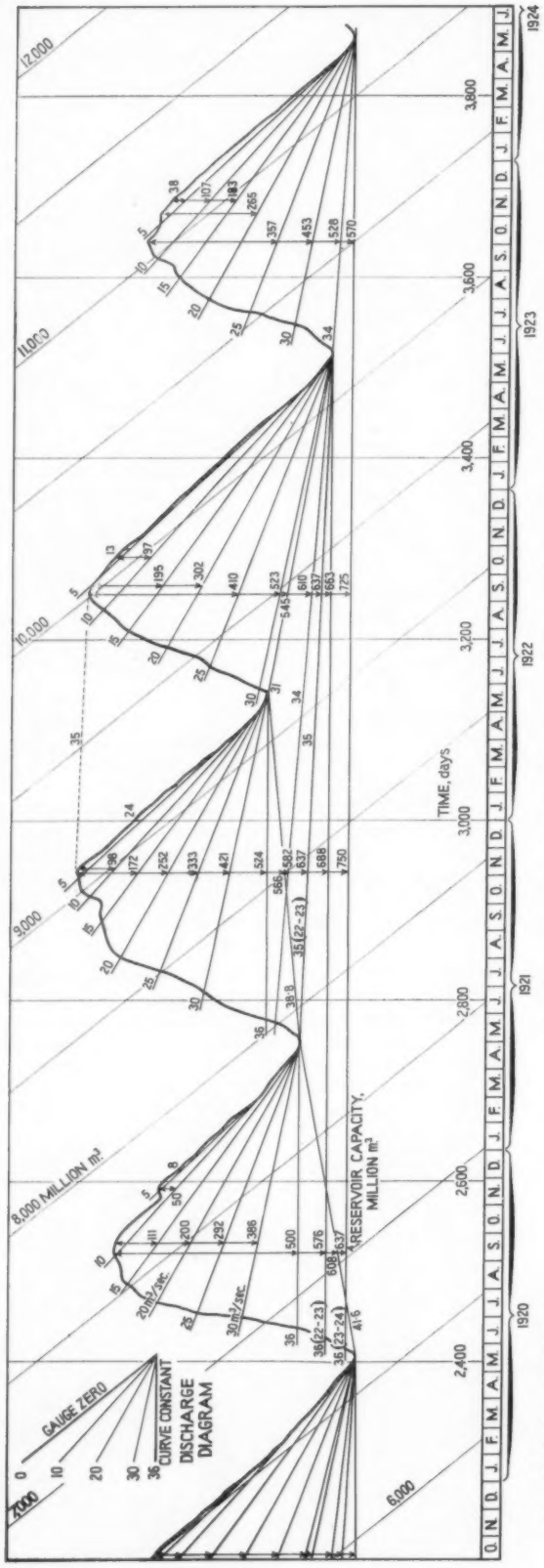


Fig. 5. Regulated discharge diagram of Röldalsvatn hydrometric station, Norway

Afflux Summation Curves

If existing lakes in the catchment are proposed to be utilised for regulation, summation curves should be established taking the *natural* regulation effect of these into account. This is calculated from their regular water-level observations and storage-capacity curves. It is not necessary to compute the difference in storage capacity from time to time. A second combined summation curve is established in which five days' progressive run-off, similar to those given in Table 1, and the corresponding capacity of the reservoir are added together. The storage capacity curve can be established for this purpose from an arbitrary datum level. If there is a significant distance between the lake in question and the discharge gauging point, the time taken by the water to travel from the lake to the gauging station must be taken into consideration.

When the afflux summation curve is established and thus the natural regulation effect of a lake eliminated, the designed lake storage in its full capacity can be applied in calculation of regulation yield.

When establishing afflux summation curves in a warmer climate, evaporation losses from the surface of the lake or reservoir must be considered carefully. For lake regulation, however, it will often be found convenient and practical to let the curve represent inflow minus evaporation, the total of which is the water available to play with.

If it is not proposed to utilise a lake for river regulation, the summation curve for gauging stations farther downstream should be established without considering its natural effect. On the other hand, if the regulation curve from this catchment has to be transferred to an adjacent area with no lakes as a natural regulation factor, the afflux summation curve should be applied for the calculation.

After reservoirs are constructed on a river, the storage effect of these must be taken into account in order to get summation curves conforming to natural conditions.

Examples on Application of Regulation Curves

A median regulation curve expressed as percentages is given as follows:

q_r	S	q_r	S
		55	14·0
12	0·0	60	16·6
15	0·4	65	19·3
20	1·6	70	22·1
25	2·8	75	25·0
30	4·1	80	28·0
35	5·6	85	31·4
40	7·4	90	35·2
45	9·4	95	39·7
50	11·6	100	45·3

Let us assume that this is a yearly regulation curve, with no water carried over from previous years. A perennial regulation curve usually becomes more unfavourable for higher regulation percentages than these figures will indicate.

Example 1: Suppose that this regulation curve is established for a catchment *A*, where the average annual run-off is 1 million acre feet (1,383 cusecs). A reservoir is surveyed and the effective capacity cal-

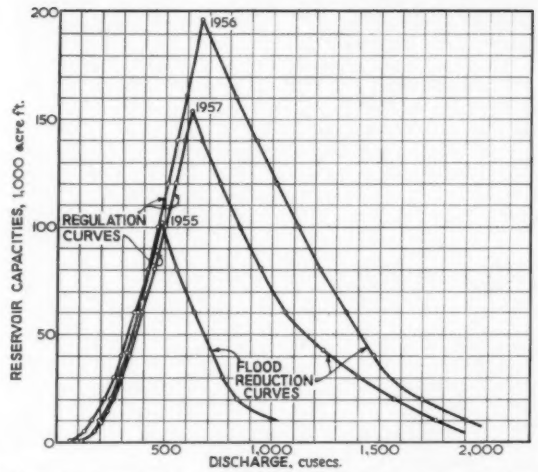


Fig. 6. Regulation and flood reduction curves for Igawa

culated to 250,000 acre feet. This gives a storage percentage of 25. The reservoir is located at *A* or in such a place in the catchment that it can be filled in a median year. From the curve a regulation percentage of 75 is extracted which corresponds to a regulated discharge of 1,037 cusecs. The median minimum rate of flow is 12% (166 cusecs) and the increase of river flow due to regulation is (1,037 – 166) cusecs = 871 cusecs.

Example 2: Suppose now that the water utilisation point is not at the dam site *A*, but at a point *B* farther downstream. No river flow records exist for *B*, but the type of catchment, exposure and orientation is about the same at *A*, and the river flow can be estimated to be say 50% more than at *A* (1·5 million acre feet or 2,075 cusecs).

Using the same regulation curve, the calculations will be as follows:

Storage percentage ... ... = 16·67
Regulation percentage ... ... = 60·1
Regulated flow ... ... = 1,247 cusecs
Increase in river flow (1247 – 249) cusecs ... ... = 998 „
Increase from calculation in Example 1 (998 – 871) cusecs ... = 127 „

It will be seen that when hydrological conditions are relatively the same, it is more economical, purely from a hydrological point of view, to build or utilise a reservoir in a large catchment than in a small one. The storage percentage is less and thus the tapping period shorter for the same size of reservoir. The yield therefore becomes correspondingly higher. The example is as illustrated in Fig. 7. If an even flow is required at *B* the flow at *A* becomes uneven as shown by the curve *bid*. The regulated flow at *A*, as defined in this article, is determined by the same regulation percentage as at *B*, 60·1% of the average which is equivalent to 831 cusecs. The average flow over the tapping period at *A* is still 1,037 cusecs.

If there are more points on the same river where regulated flow must be calculated, the procedure is as follows:

1. Points between *A* and *B* get the same regulation percentage as at *B*.

2. Points downstream of *B* get the same *increase* in river flow as *B*.

If the point is far downstream, evaporation losses must be taken into consideration.

If the low flood period for *B* and points farther downstream do not coincide, the regulation will have a decreasing effect for the downstream stretch of the river. This can be seen from graphs similar to those in Fig. 7 when the two points *c* and *h* occur at different times.

Example 3. Suppose that two utilisation points are located as on Fig. 8. In *A*'s catchment is a reservoir S_1 and between *A* and *B* is another S_2. If the storage percentage for *A* is greater than for *B* the reservoir S_2 should be considered as regulating the partial sub-

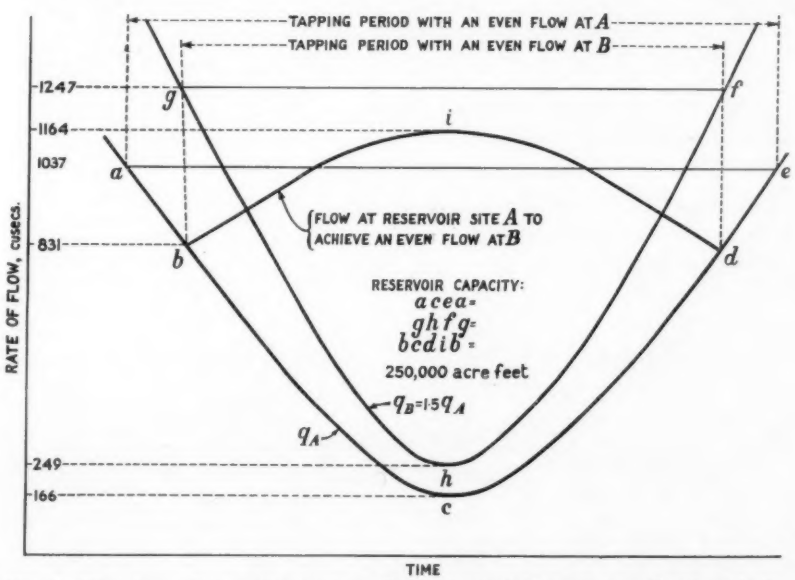


Fig. 7. The downstream decreasing effect of regulation at low flood periods

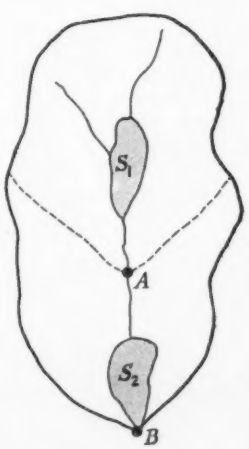
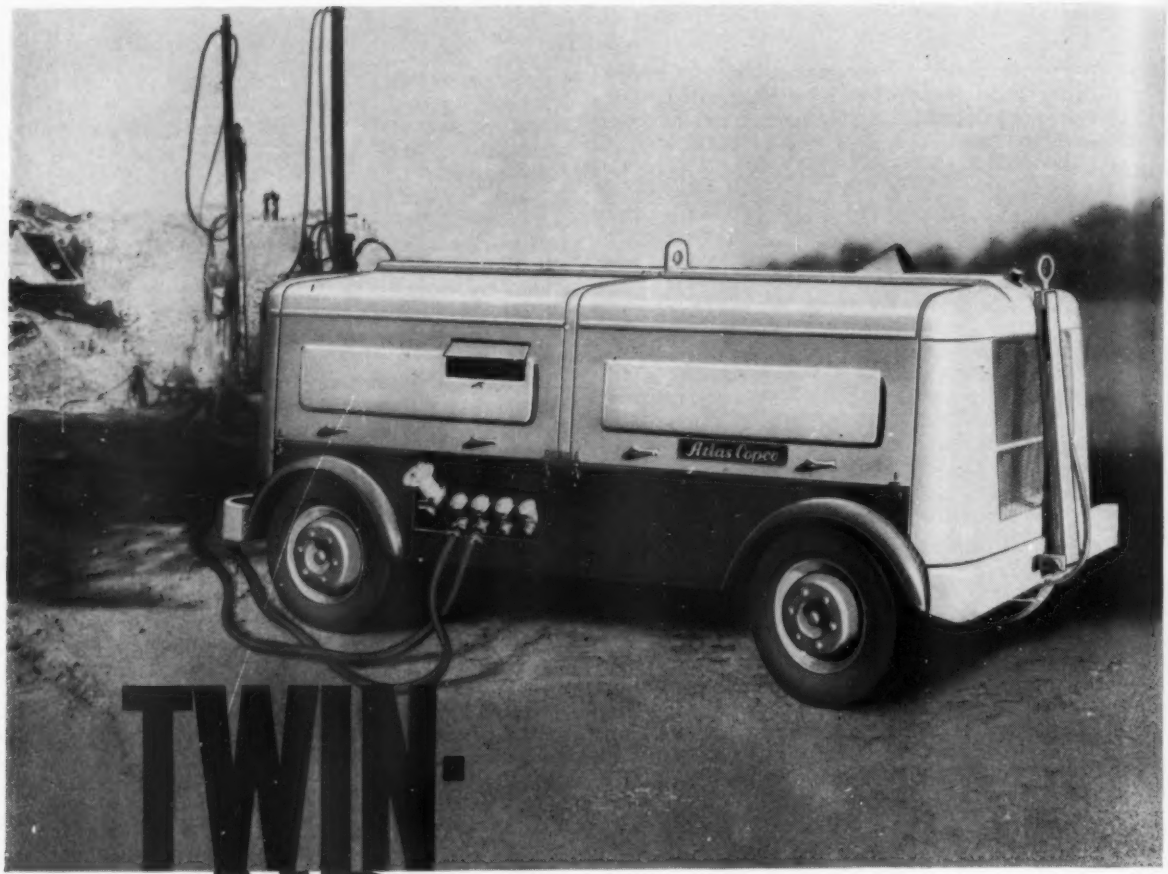


Fig. 8. Scheme of two utilisation points



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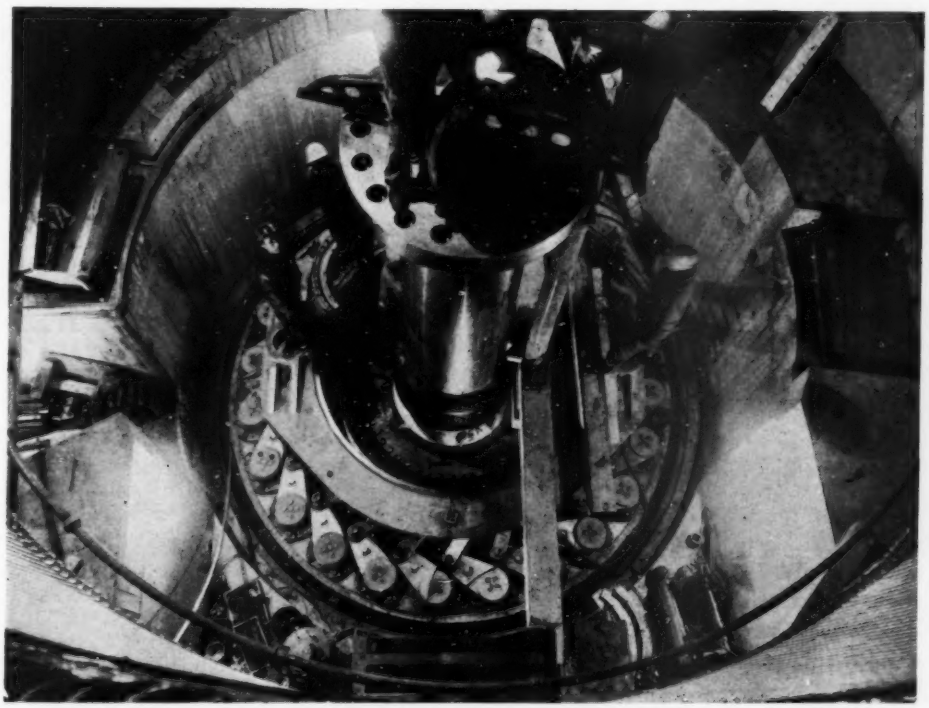
catchment between A and B only. The discharge at A is calculated separately and the actual regulated flow at B will be the total of these two. If on the other hand the storage percentage at B is greater than at A, the storage S_2 would enable the regulation of some of the water from A. The regulated flow at B is therefore calculated for the entire catchment, taking both reservoirs as one. The regulated flow at A would be as previously calculated.

These are but a very few generalised examples on the application of regulation curves. In practice many special factors may come into the calculations, draw-off for irrigation, short-time regulation, special laws and rules for water utilisation, etc. It has nevertheless been hoped that the general method has been explained in such a manner that it can be applied by the reader, as and when required, to the particular problems with which he is faced.

Chute-des-Passes Turbines

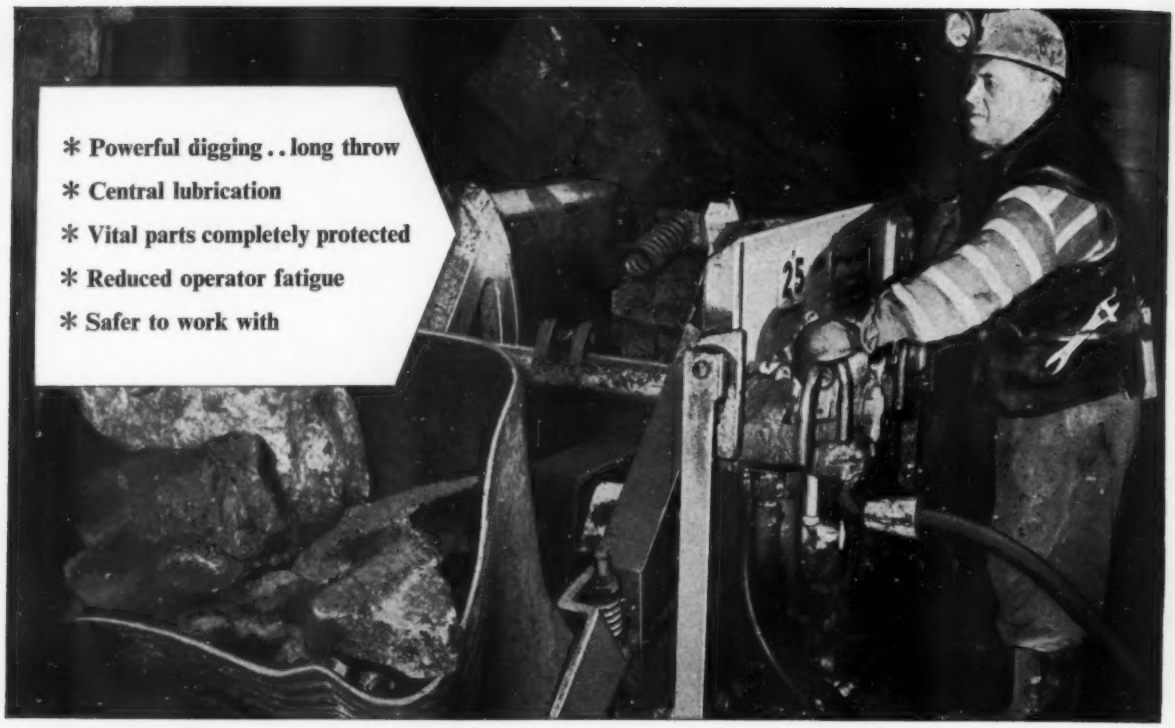


One of the turbine pits at Chute-des-Passes with installation work in progress

The first two of five 200,000 h.p. hydraulic turbines, the most powerful in North America, are now in commercial operation at the Chute-des-Passes power plant of Northern Quebec, Canada. Each has a rating 20% higher than the units at Grand Coulee on the Columbia River. The project, which was described in WATER POWER, May 1959, issue, is to provide additional electricity for the smelters of Aluminum Company of Canada Limited, and will cost $150 million. When it comes into full operation, early in 1960, it will increase the capacity of Alcan's and its affiliates' Saguenay hydro-electric system in Northern Quebec by nearly a third, to a total of 3,600,000 h.p. All five turbines were designed by The English Electric Co. Ltd., Rugby, England, and built by the John Inglis Co. Ltd., Toronto, a member of the English Electric Group. An interesting feature is that the governors for the vertical Francis turbines are of the magnetic-amplifier type, permitting all five turbines in the power station to be controlled together as a single machine. This is relatively new to North America, and the Chute-des-Passes power station is the first million horsepower plant to use this system. The station itself is underground, some 450 ft. below the surface, and is fed by the water from nearby Lake Peribonka by a six-mile long concrete-lined tunnel 34 ft. in diameter. At the net head of 540 ft. each turbine develops 200,000 h.p., but at the maximum head of 640 ft. each is estimated to have an output of 265,000 h.p.

Glenfield Cone Valves

Essentially the cone valve is similar to a conventional plug cock, having the plug axis either vertical or horizontal and being readily arranged for driving by manual, electric, hydraulic or pneumatc power. Glenfield & Kennedy Limited have fairly recently issued a range of valves in regular sizes from 15 to 48 in. in diameter and for working pressures from a head of 289 to 580 ft. The seats are of Monel metal, deposited by weld on the parent metal and machined to match the plug faces. The actuating mechanism,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* Central lubrication
* Vital parts completely protected
* Reduced operator fatigue
* Safer to work with

LM56 SHOVEL LOADER *loads 65 cu. yds. an hour*

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Bucket operating and traction motors are of the vane type—rapid in action, simple in design. The LM56 has a higher total motor capacity than any comparable machine. The bucket bites deeply into the muck pile and becomes well filled. With its strong and rapid throw, the LM56 fills even long cars to capacity.

Central lubrication simplifies maintenance

Synchronized to the working tempo of the loader, the central lubricator supplies the right quantity of oil to the right part of the machine at the right moment. The daily control can thus be confined to one lubrication point only. Oil delivery is easily regulated by a screw on top of the lubricator and checked through a glass tube.

Vital parts completely protected

LM56 is not affected by the water and dirt that surround it underground. The vital parts are completely protected by special sealings, and the amply proportioned gears are made to withstand the stresses of rough work. That is why it gives long and reliable service under the toughest conditions.

Special silencers and new controls reduce operator fatigue

LM56 is remarkably silent running and easily operated. Each motor is fitted with a separate absorption silencer enclosed in the gear box.

Loading capacity is commonly given as theoretical capacity, obtained by multiplying the loading cycle with the bucket capacity. Such ideal conditions may conceivably be approached when loading sand or gravel. The capacity of LM56 is a realistic average obtained from numerous time studies of ore loading under normal working conditions.

Smooth working air controls, of a completely new design, are also fitted with special silencers.

Safer to work with

LM56 is carefully designed for maximum safety. One quick movement of a valve lever and the machine is immediately shut off and cleared of air. This makes service and repair work safer and easier. The air control levers are easily locked in a neutral position so that the machine cannot be set in motion by accident. The operator's feet are protected by a safety rail in front of the wheels.

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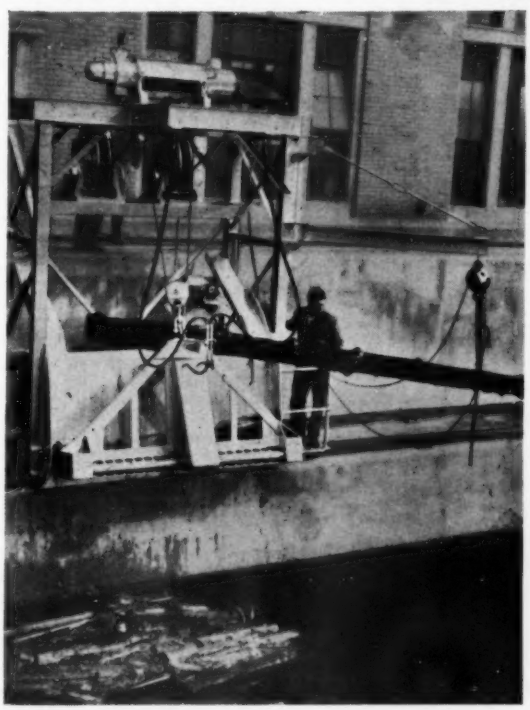
which is the same whatever form of power is used, is designed to lift the plug free of its seatings, turn it about its axis through 90°, and reseat it at the end of its travel.

Standard valves are designed for use in the fully open or fully closed positions only and as the bore of the plug coincides with that of the body, the waterway contains no pockets where very low pressures could form or cavitation occur. The valve is supplied complete with local or remote-control push buttons, local indication of the seated and unseated position, and limit switches for turning the operating motor. In addition, provision is made for manual operation in the event of a power failure and the gear incorporates safety interlock switches to guard against any untoward experiences. A full account of this series of valves is given in the December issue of the *Glenfield Gazette*.

Portland Hydraulic Rack Rake

The accompanying illustration depicts a new design of trashrack rake developed by The Portland Company, 58 Fore Street, Portland, Maine. The teeth of the rake can be opened and closed by a hydraulic mechanism incorporated in the rake head and supplied through flexible tubes from a hydraulic power unit on the traversing carriage. When the rake is being lowered the teeth hang vertically; they thus ride clear of obstructions on the rack and dig into any accumulation at the bottom of the rack. The teeth are then closed to the horizontal position, so that on the upward travel of the rake the bottom accumulation is removed and all debris on the rack bars is lifted away.

No channel guides or other special attachments are needed, as the rake is furnished with flanged wheels which register with the rack bars but can ride over any obstructions on the downward travel.



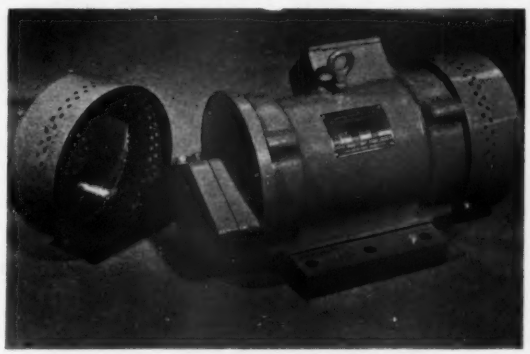
The hoist carriage can be arranged with a trash hopper for a sluiceway, with a built-in trash car, or to feed separate trash cars. Power operation is normally supplied for both rake operation and carriage traverse, but a hand traverse can be supplied if preferred.

The Portland hydraulic rack rake can be handled by one man, and the illustration shows one man retrieving a waterladen log that was dredged up from the bottom.

Motor for Vibrating Drives

A new electric motor specially designed for vibrating drives, the first of its type to be made in the United Kingdom, is being produced jointly by The English Electric Company Limited and the Grantham Electrical Engineering Company Limited.

The completely self-contained unit provides an inexpensive and reliable drive by eliminating all the mechanical parts associated with an eccentric shaft arrangement. Vibration is generated by out-of-balance

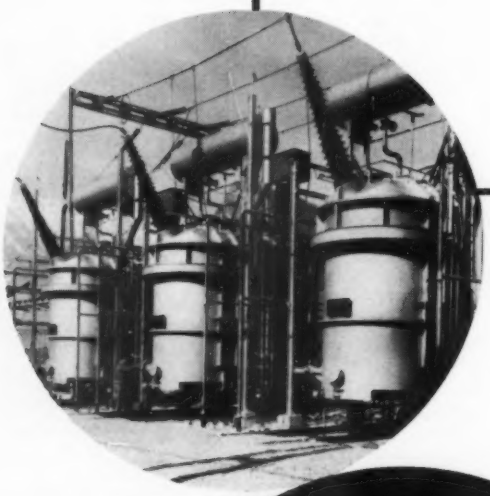


weights at either end of the motor which can easily be adjusted by single bolts to give the required output. Tests have shown that a bearing life of many thousand hours can be expected.

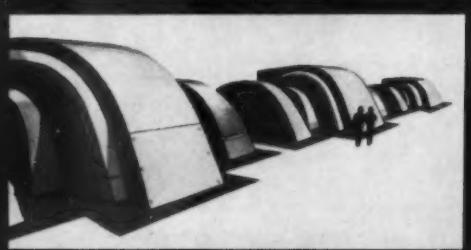
The motor is totally enclosed, dust-proof and weather-proof. The frame is of nodular cast iron, with integral feet, and the shaft is of high tensile steel to withstand the high centrifugal forces to which it is subjected. Because of its vibrating motion, the motor must be mounted on a resilient base. Operating at 1,500 r.p.m. synchronous speed, it has a power output of up to 7,500 lb. centrifugal force, or 10,000 lb. at 3,000 r.p.m., which is ample for all applications at present envisaged. The motor is operated from a 3-phase 50-cycle supply at 110–650 V. Greater outputs and other supply frequencies can be provided.

It can be used wherever a vibrating motion is required. Typical examples are drives for screening, hopper and continuous drying systems (especially those for dealing with loose material in bulk quantities), tamping equipment (e.g. for pre-cast concrete) and machines for breaking or grinding down material such as granite.

Various sizes are available equipped with $\frac{1}{2}$ to $1\frac{1}{2}$ h.p. motors and exerting a centrifugal force of from 2,000 to 7,408 lb. The new motor is being marketed by both English Electric, Bradford, and the Grantham Electrical Engineering Company, 6 Wharf Road, Grantham, Lincs.



Power Stations and Substations



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Abstracts from the World Technical Press

Cableway Towers in Czechoslovakia

This article is devoted to the three sets of cableway towers, moving on parallel tracks, which were used at the construction site of the Orlik dam. The head towers, the largest of their kind ever made in Czechoslovakia, have the following characteristics: capacity, 20 tons; buckets, 6·5 cu. m.; span, 695 m.; hoist, 120 m.; hoisting speed, 130 m. per min.; hoist motors, 2 × 255 kW; crab travel, 2 × 255 kW; tower travel, 2 × 66 kW; carrying cable tightening, 2 × 12 kW; rubber cable winding, 2 × 2·5 kW. Ward-Leonard-set driving motor, 850 kW; two 550 kW d.c. generators. The base of each tower is a massive undercarriage of welded solid-web girders, mounted on four vertical and two horizontal bogies with a total number of 48 travelling wheels. The tower proper, rectangular in plan, is a closed structure with several floors on which are accommodated the drive for the tower, the cable guides for the winches, the engine room with the cable winches, and, at the top, the room for the Ward-Leonard set and other electrical equipment. From the front wall of the upper floor, a 25 m. boom slants upwards, carrying at its tip a control cabin of light metal from the desk of which the operator directs all the operation of the tower. There are two levers for crab travel and hoist, and two pedal switches each governing one direction of travel of the whole tower. The cabin, which is well insulated against extreme differences of temperature, is fitted with a defroster and window wipers. A telephone connects the operator with the winch and electrical machinery rooms in the tower; otherwise, wireless control is used throughout, thus ensuring accuracy of operations even when visibility is poor. The tail towers are considerably simpler in design and construction; otherwise the tower drive and the winding equipment of the electric cables are similar to those of the head towers. The carrying cables are tightened by 16 pulley blocks with electric winches. (Vaclav Nevrlý, *Indian Journal of Power and River Valley Development*, Vol. IX, No. 8, August 1959, p. 23, 6 pp., 8 ff.)

NOTE: A more detailed article on the same subject by the same author, who actually designed the Orlik cableway towers, appears in *Czechoslovak Heavy Industry*, No. 12, 1959, p. 2, 11 pp., 11 ff.)

The Zervreila Hydro-electric System

This chain of three plants harnesses the waters of the upper Vals and Safien valleys. The characteristic feature of the scheme is that the water impounded, instead of flowing naturally into the Vorderrhein, is diverted through pressure tunnels aggregating 34·5 km. in length to Rothenbrunnen, the downstream plant of the chain, whence it reaches the Hinterrhein which, at this point, lies 1,200 m. below. Construction work was therefore spread over three valleys through tunnels driven across two mountain ridges. At the uppermost end of the catchment, the Zervreila hollow offered an uncommonly favourable storage possibility, and the reservoir created by the 150 m. high dam at the narrow downstream end of the hollow has a useful capacity of no less than 100 million cu. m. of water. A rockfill dam closes the Vals to form a balancing reservoir which receives the discharge of the two 10,000 kW turbines of the power house built on the left bank, close to the toe of the Zervreila dam. In the summer months, the required additional volume of power water is conveyed from the Peilerbach to the Zervreila balancing reservoir, whence two 3,000 kW pumping sets, provided in the power house, lift it into the main reservoir. A gravity tunnel conveys the discharge of the Zervreila plant to a second balancing reservoir at Wanna, in the upper Safien Valley and farther downstream, through a surge tank and a pressure shaft, to the two 37,500 kW turbines of the Safien-Platz plant, which, in its turn, discharges into a third balancing reservoir. From this reservoir, a pressure tunnel and a pressure shaft feed the three 37,500 kW turbines of the Rothenbrunner plant, the final stage of the system, which lies close to the 10-year-old 25,000 kW generating plant at Rabusa, now amalgamated with the Zervreila system. The scheme's average annual production is assessed at 530 million kWh, of which 320 million kWh are available during the winter months. An overhead line transmits the energy produced at Zervreila to the 50/150 kV outdoor switchyard and transformer station at Safien Platz, whence it proceeds by means of a double line to the Rotherbrunner switchyard and transformer station, where the three partners of the Zervreila group (Kraftwerke Sernf-Niederenbach A.G., Schwanden; Motor-Columbus A.G., Baden; Nordostschweizerische Kraftwerkr A.G., Baden) can draw their supply at either 150 or 220 kV, as required. The contracts for construction work and supply of equipment were placed on June 24, 1953. Impounding at Zervreila began about four years later, and after the commissioning of the power plants in 1957 and 1958 the installations were officially inaugurated on September 5, 1959. (*Bulletin de l'Association Suisse des Electriciens*, Vol. 50, No. 22, October 24, 1959, pp. 1097/1098, 2 ff.)

The Lipno Dam

This Vltava dam, 296 m. long at the crest, is a composite structure which comprises a gravity concrete spillway section on the left bank, and an earthfill section on the right bank. This article deals on the main with the major problems encountered in the building up of the earthfill bank, which takes no less than 208·5 m. of the whole length of the dam. The two dam sections were built each in a separate foundation pit, the gravity section first, from 1952 to 1956, and the earthfill bank from 1956 to 1957. Founding the earthfill on the river bed and on the right bank presented awkward difficulties, since the whole of the right bank of the Vltava river at the dam site consists of detrital material, which, in addition to being inadequately impervious, is not easy to use in earth and foundation work. To ensure the imperviousness of the earthfill foundation, a concrete curtain 2·5 to 3 m. thick, was sunk right down to the sound rock, about 20 m. below the surface. This concrete curtain bears off in plan from the axis of the dam so as to connect with the impervious clay core which slants down from the top of the dam. The curtain is founded on ten 3·5 × 14·4 m. caissons within the river bed proper, and, without, on eleven 2·5 × 12 m. timbered

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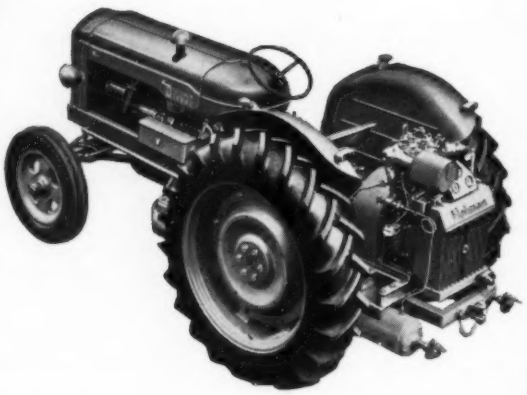

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pits. Upon completion, the pits were used for drilling grouting holes into the foundation rock, at the rate, in each pit, of six core holes, and three control holes averaging 20 m. in depth. In three of the lower sited pits, affected by substantial water intrusion, grout was gradually injected behind the timbering to fill hollows scooped out by the water and the whole space between the rock and the timbering. Most careful attention was devoted to this particular job, especially after pit No. 10 had collapsed. The portion of the curtain founded on caissons proved a much easier proposition, and there was no trouble, except at the caisson nearest the left bank. While being sunk, it reached the bedrock sooner than forecast from the geological profile and concreting progressed with the sinking of the caisson. Building up of the bank on the foundation platform was ready to begin at the end of July 1956, but owing to very bad weather in August and October, only 35,000 cu. m. of fill, a mere 13% of the total volume, had been placed by the end of the year, most of it in the stabilisation zone. This left about 220,000 cu. m. of fill (160,000 cu. m. of unscreened clay) to be placed during the first seven months of 1957. The highest monthly figure was attained in July, when 40,037 cu. m. were placed, the record for 24 hours being 2,950 cu. m. The high standard of the work was proved by control measurements taken during the summer months of 1958: between October 1957 and June 1958, there was a settling of the dam bank of no more than 32 mm. A detailed account of the tests carried out in the various zones of the bank occupy almost two pages of the article, which also includes sections on the construction plant and on the mechanical equipment used in the building up of the earthfill dam. (Ing. Jan Skalický, *Inženýrské Stavby*, Vol. 7, 1959; No. 9, p. 322; No. 10, October 1959, p. 381; 4 pp., 2 ff.)

Trebišnjica River Development

Before listing briefly the main features of this two-stage development, the author discusses at length the conditions, hydrological, geological and other, obtaining in the Karst, a region unlike any other in Europe, consisting of fissured limestone which enables rivers to emerge from nowhere and vanish into the ground just as unexpectedly, to reappear and disappear again miles away. Characteristic of this south-western part of Yugoslavia, which actually constitutes its Adriatic catchment, are the valleys called "polje" (polyeh). They are closed at either end by steep rock ridges, and having no surface outlet, they collect the rainfall and empty through holes in their floor or at the foot of their steep banks. In the autumn and winter, when the rain intake exceeds the discharge capacity of their natural dewatering system, lakes are formed which at times flood the surrounding country; at the beginning of the following summer they simply disappear, leaving the "polje" available for a short but useful period of cultivation. The Trebišnjica is just one of those typical Karst rivers that indulge in this perennial game of hide-and-seek, but the development possibilities it offers were too favourable to be missed. Field investigations and preliminary studies were put in hand in 1954, a project has since been worked out, and construction work is to start in the near future. In spite of the fact that most of its catchment is underground, extensive observations, supported by the use of dyes, have led to a fairly accurate delimitation of its boundaries. The visible four main sources of the river lie south of the town of Bileća, 330 m. above sea level, at the toe of a terrace which rises to over 420 m. The largest, called Dejanova pečina, is located in a cavern accessible, at times, to a fairly great distance, and it is from this cavern that in winter and spring the Tribišnjica appears as a sizable stream which flows southward through the sparsely-inhabited Miruša valley. A few miles north of the sharp bend of the river to the west, near Grančarevo, the valley is reduced to a narrow gorge to be closed by a 102 m. high dome-type dam, which, following comparative studies, was considered the most economical solution. The major part of the Miruša valley will thus become a 17 km. long reservoir covering a storage area of 2,800 hectares. The Grančarevo plant at the foot of the dam will house four vertical Francis turbines operating from a mean net head of 83 m. These will have an installed capacity of 160 MW and an annual production of 500 GWh. Downstream from Grančarevo, a 13 km. long balancing reservoir will be set up, on the one hand to equalise the supply of power water between Grančavero and the downstream plant at Dubrovnik on the Adriatic Sea, and on the other, to store the peak of the floods caused in the region below Grančarevo by the periodical swelling of the Sučica torrent, a left-bank tributary of the Trebišnjica. This uncommonly large balancing reservoir will be closed at Gorica by a 32 m. high dam incorporating a spillway block controlled by flap gates and a desilting culvert. Close behind will be the inlets to the two power tunnels of the Dubrovnik plant. This plant is to be erected in two constructional stages; one of the power tunnels, 15 km. long, 6·0 m. in diameter, a concrete conduit 1·17 km. long and 5·4 m. in diameter, two vertical 270 m. deep pressure shafts 4·1/3·1 m. in diameter, and a 450 m. long gravity tailrace tunnel, 9·7 m. in diameter, leading from the underground power house to the sea. The surge tanks of the two systems are interconnected. The Dubrovnik machine hall will house four vertical-shaft Francis turbines operating under a mean net head of 270 m., and designed for an aggregate discharge capacity of 180 cu. m. per sec. Its installed capacity will be 416 MW, and the yearly production is assessed at 1,900 GWh. (Ing. Edmund Klameth, *Die Wasserwirtschaft*, Vol. 49, No. 11, November 1959, p. 293, 6 pp., 9 ff.)

NOTE: The above issue of *Die Wasserwirtschaft* contains an interesting general survey, by Ing. Josef Bartsch, AEG Frankfurt-on-Main, of the progress made in turbines and generators as used today in recent hydro-electric developments, pumped-storage plants included. (p. 282, 7 pp., 12 ff.)

The Power Potential of Rivers

The power potential of modern hydro systems is a complex problem, and present methods of determining it are not entirely satisfactory. According to the method described in this paper the energy potential of a river is determined by regulating the total power production of the system instead of the flow at a particular site. The proposed method is a generalisation of the concepts introduced by Don Johnstone and John W. Hackney, and determines the following quantities: (1) total power and energy production of the system; (2) installations of the individual plants, based on a given prime system load factor. The paper

gives the theoretical basis for the computation and includes an example of the application of the method to a typical hydro system. (G. S. Cavadias, *The Engineering Journal*, Vol. 42, No. 10, October 1959, p. 103, 5 pp., 6 ff.)

Vesdre Development

The gravity arch dam built near Eupen across the Vesdre river, downstream from its confluence with the Getsbach, one of its left-bank tributaries, marks the first step in carrying into effect an extensive programme of multi-purpose schemes. Following the impounding of part of the Helle river waters by means of a 1,200 m. tunnel, the catchment area of the scheme has increased from 69·2 sq. km. to 105·95 sq. km., and the reservoir, with a useful capacity of 25 million cu. m., will now be able to meet actual requirements of 71,500 cu. m. a day. The dam itself, about 410 m. in length, has a radius of 375 m., is 55 m. thick at the base, 8 m. at the top, and carries an 11 m. roadway with cantilever footways at the top. The dam is a concrete structure, with a watertight concrete facing upstream, and consists otherwise of blocks of mass concrete 15 m. × 6 m., 2 to 3 m. thick, cast on site and laid overlapping. The spillway consists of two 12·5 m. wide openings designed for an aggregate discharge of 230 cu. m. per sec., equal to three times the highest flood recorded heretofore, and of a stepped energy dissipator. The generating equipment comprises two 600 kVA and a 200 kVA sets which, together with the 400 kVA available at the purification plant, can supply 3 to 4 million kWh a year, exclusive of internal service requirements. (*La Technique de l'Eau*, Vol. XIII, No. 154, October 15, 1959, p. 32.)

Whitedog Falls and Caribou Falls

A comprehensive description is given of these two projects on the Winnipeg and English rivers, designed by the Ontario Hydro engineering staff and carried into effect as a combined operation by the Ontario Hydro Construction Division. Whitedog Falls, 17 miles north of Minaki on the main C.N.R. line, has a rated head of 50 ft. and a rated capacity of 81,000 h.p., the corresponding figures for Caribou Falls, 17 miles farther to the north-west, being 58 ft. and 102,000 h.p. The installations of the two developments and construction work are described at length. (N. S. Haines, *The Engineering Journal*, Vol. 42, No. 10, October 1959, p. 73, 12 pp., 11 ff.)

Hotzenwald Project

This new long-term project of the Schluchsee A.G., Freiburg, is to harness in three pumped-storage plants the waters of the Hotzenwald, which form the southern part of the Black Forest between the Hauensteiner Alb and the Wehra rivers. The backbone of the new development will be the 60 million cu. m. storage reservoir created by an 85 m. high dam across the Schwarzenbächle in the upper catchment area of the Hauensteiner Alb. The normal water supply available is to be supplemented by water pumped from the Rhine, and the 640 m. head between the Lindau reservoir and the Rhine at Säckingen is to be utilised in two underground plants: Hierholz, upstream, close to the southern tip of the reservoir, and Säckingen, downstream, north of the town of the same name. Two daily-storage reservoirs provided by smaller dams at Ibach, south of the Hierholz plant, and at the Sulbach, north of the Säckingen plant, will act as balancing reservoirs. A pressure tunnel, 16 km. in aggregate length, will connect the two plants and the balancing reservoirs. The third stage of the system, utilising a head of 630 m. in an underground plant at Wehr, will be supplied from an upper reservoir near Hornberg and from a lower reservoir in the Wehra valley, upstream from Wehr. This third stage will be connected with the two other stages by means of an open conduit through which flood water of the Wehra, pumped into the Hornberg reservoir, will be diverted into the Lindau yearly reservoir. When completed, this new system of peak-period plants will add a regulating capacity of about 1,780 MW to the West-German grid system; the average yearly production at peak periods is assessed at 1·5 TWh. The project is to be carried into effect within the next 15 to 20 years. (Schr., *Wasserwirtschaft*, Vol. 49, No. 10, October 1959, pp. 279–280, 1 map.)

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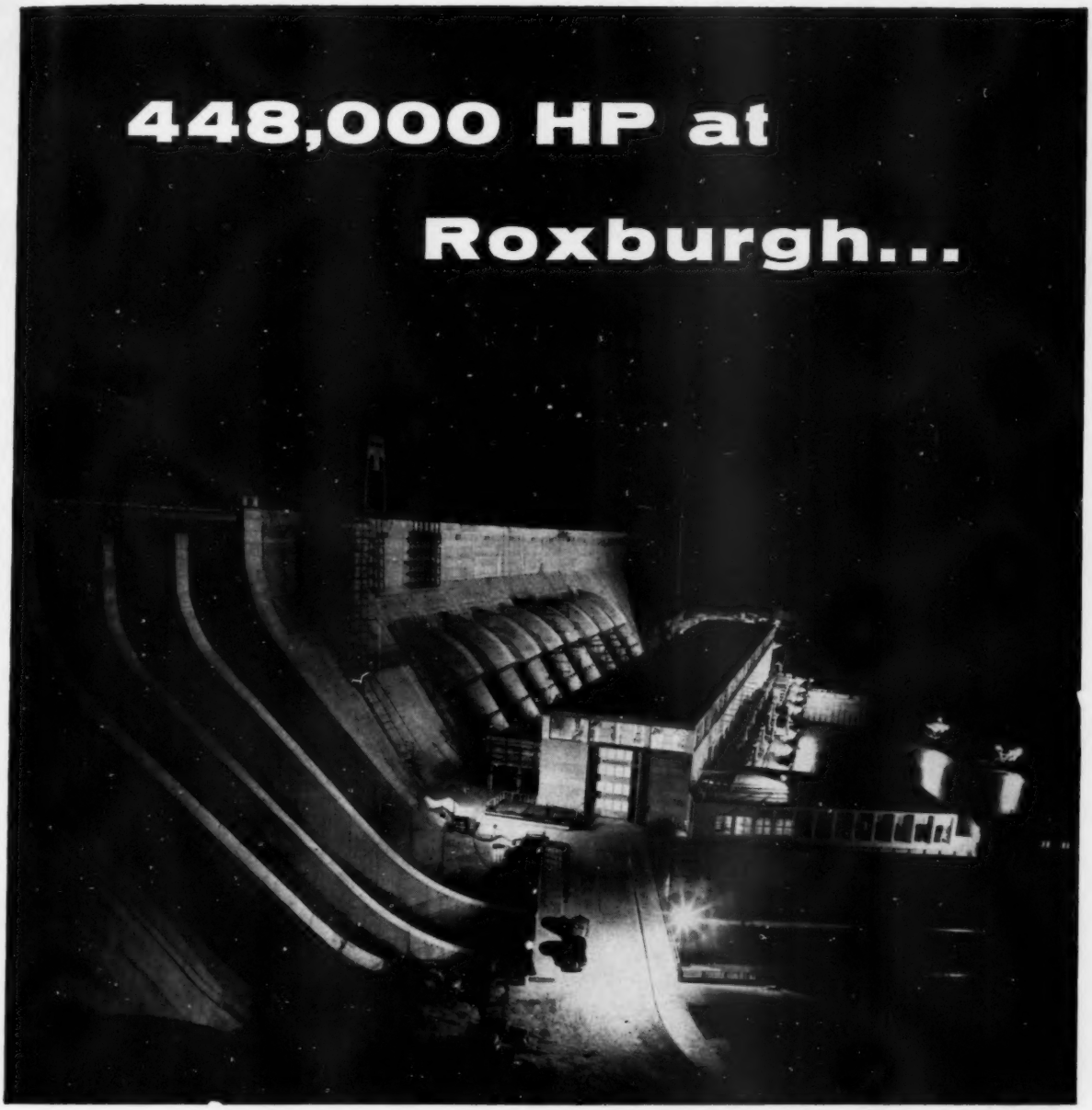

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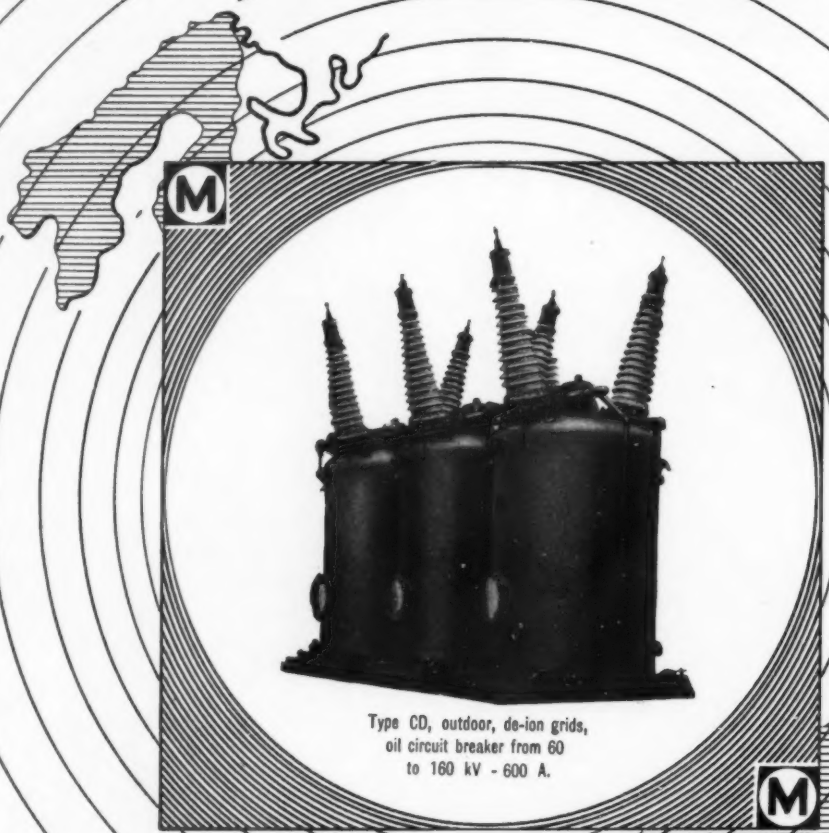

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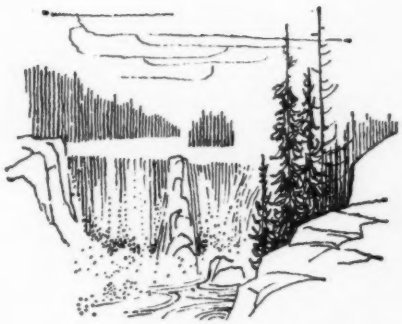

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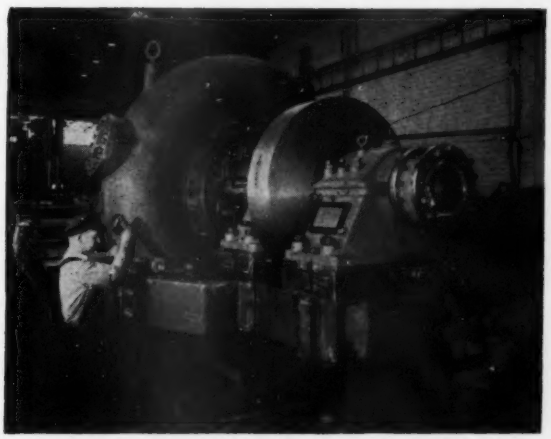

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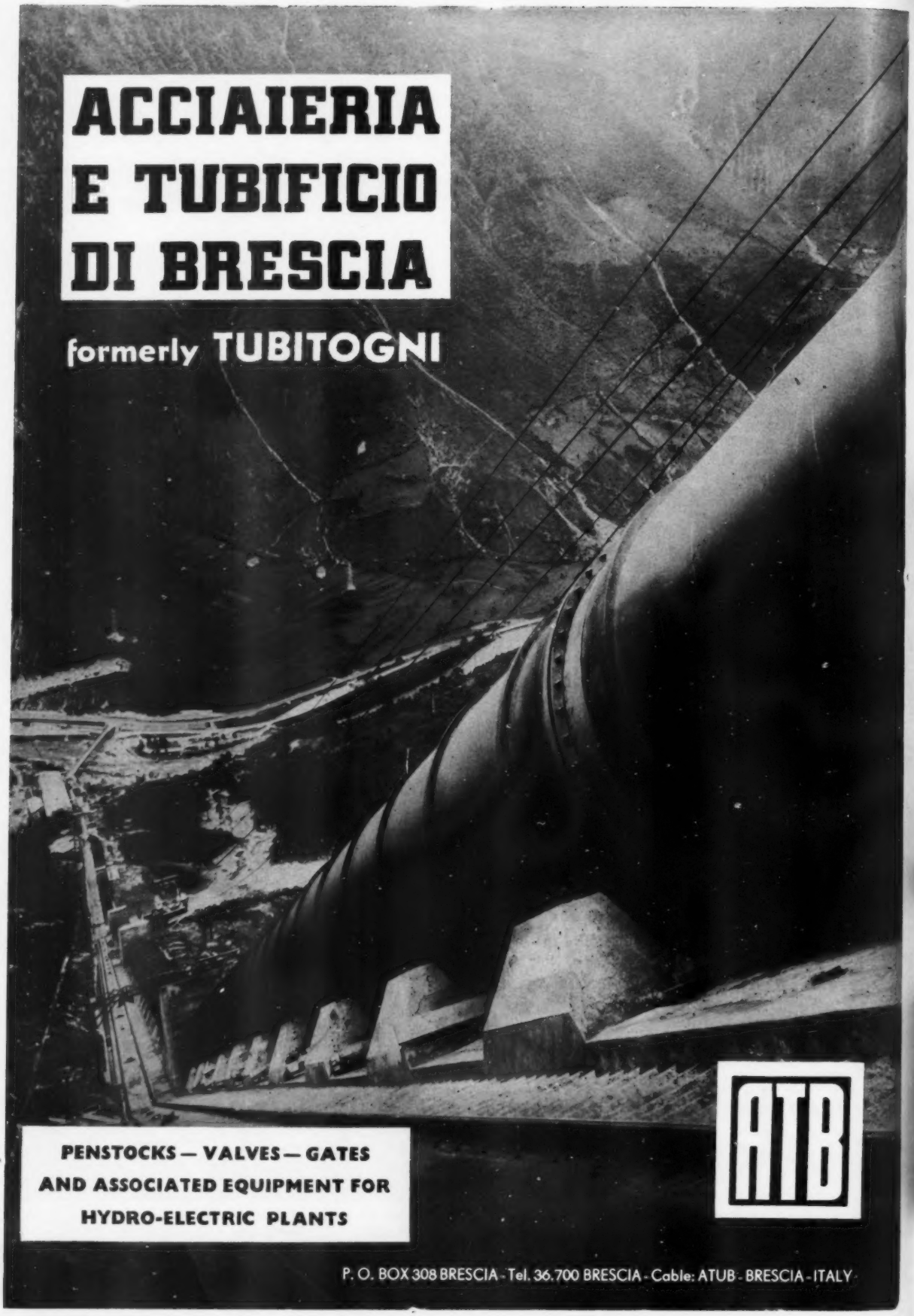

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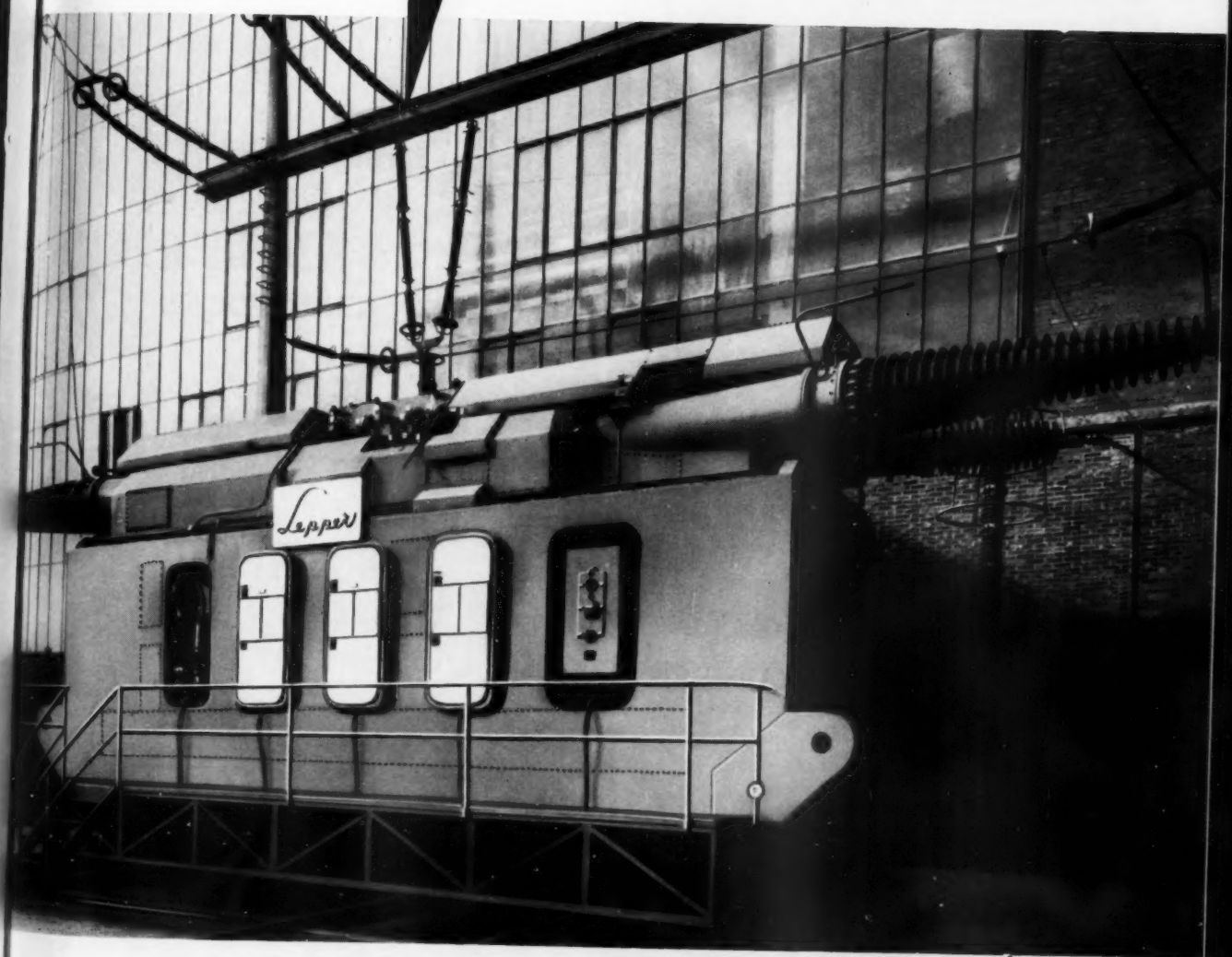

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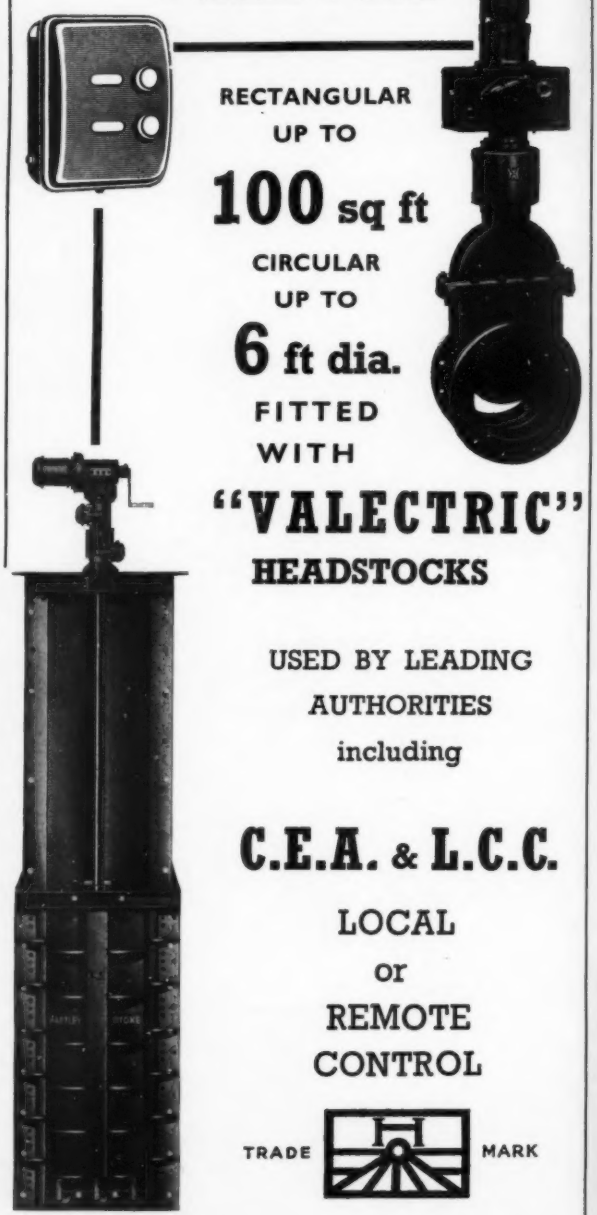

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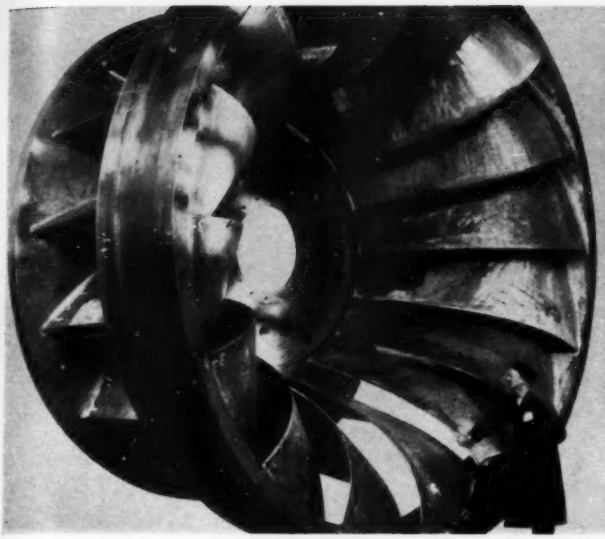

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RINCON DE BAYGORRIA Uruguay In service 1959	3 Kaplan	48-2	14-7	49.500	79	With regard to dimensions, South America's largest turbines.
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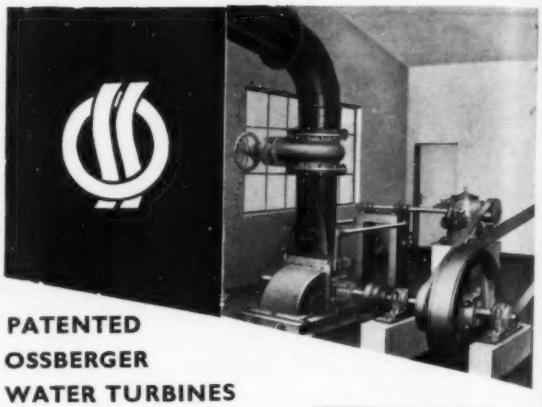

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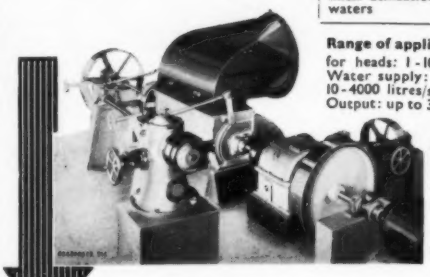

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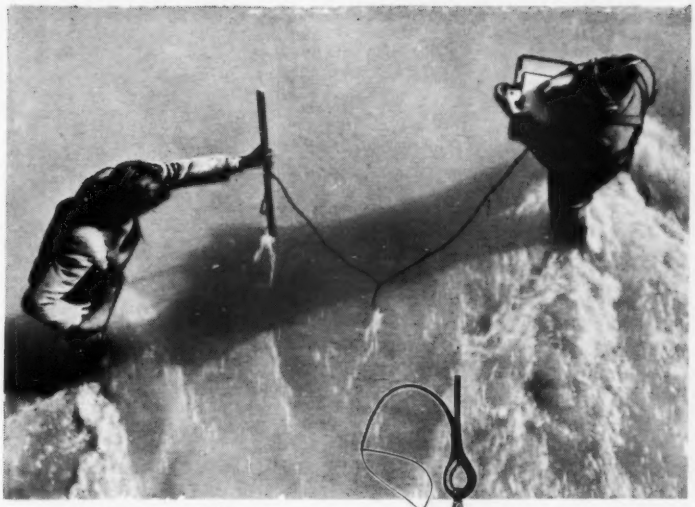

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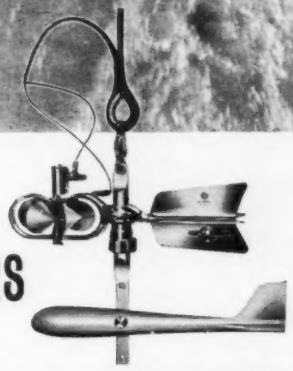

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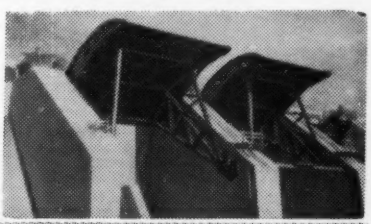

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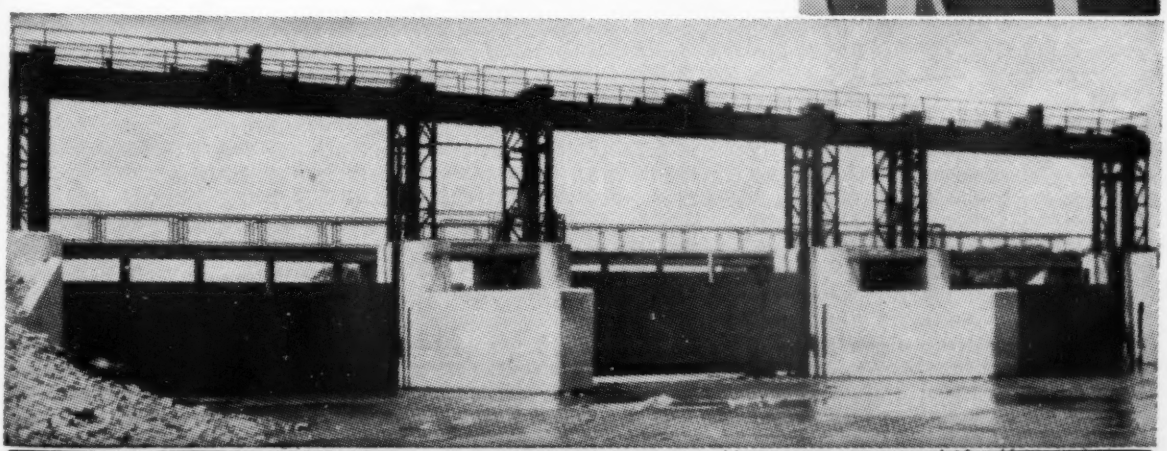

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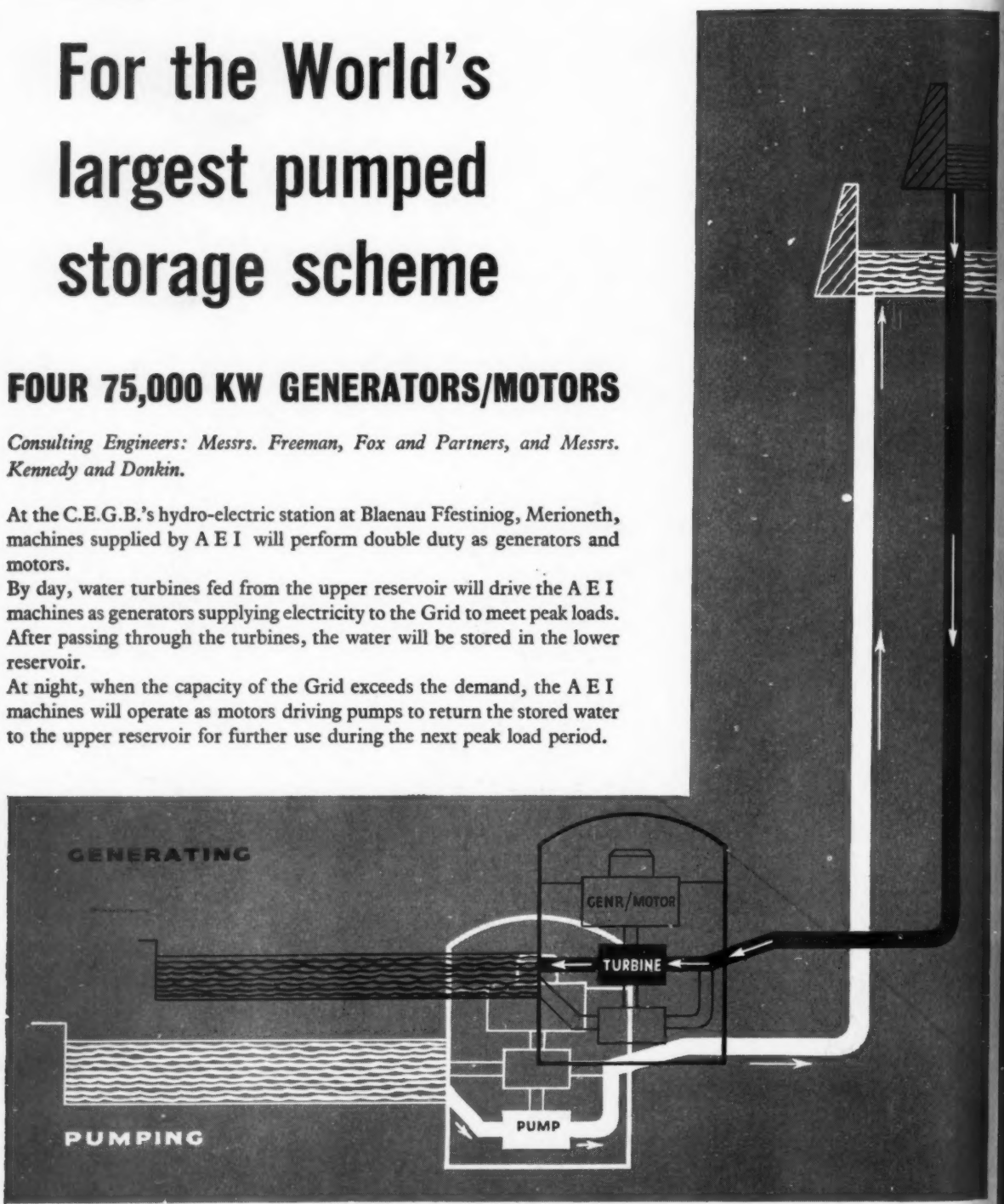
Consulting Engineers: Messrs. Freeman, Fox and Partners, and Messrs. Kennedy and Donkin.

At the C.E.G.B.'s hydro-electric station at Blaenau Ffestiniog, Merioneth, machines supplied by A E I will perform double duty as generators and motors.
By day, water turbines fed from the upper reservoir will drive the A E I machines as generators supplying electricity to the Grid to meet peak loads. After passing through the turbines, the water will be stored in the lower reservoir.
At night, when the capacity of the Grid exceeds the demand, the A E I machines will operate as motors driving pumps to return the stored water to the upper reservoir for further use during the next peak load period.



ASSOCIATED ELECTRICAL INDUSTRIES LIMITED

HEAVY PLANT DIVISION — RUGBY AND MANCHESTER, ENGLAND

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